SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Record of Sanitation—Fair

Alternating Double Filtration—Daviss

Pumping Station Design—Kennedy

Penicillin Wastes Treatment—Muss

Dye Adsorption Studies—Thornton, Moore

International Boundary Waters Survey—
Berry, Black, Oeming

APRIL, 1951—VOL. 23, No. 4

Make Plans to Attend

TWENTY-FOURTH ANNUAL MEETING

OF THE

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

IN CONJUNCTION WITH

CENTRAL STATES SEWAGE WORKS ASSOCIATION

MUNICIPAL AUDITORIUM

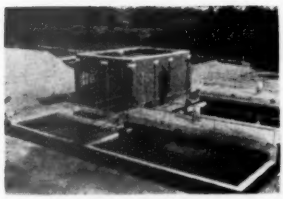
ST. PAUL, MINN.

October 8-11, 1951

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

325 ILLINOIS BUILDING CHAMPAIGN, ILLINOIS

Specify CHICAGO "PAKAGE" PLANTS



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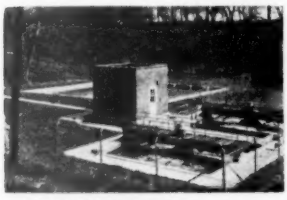
• FOR INDUSTRIAL PLANTS
Goodyear Tire & Rubber Co., Topeka, Kan.



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16 YEARS OF PROVED PERFORMANCE

Chicago "Pakage" Plants were a major departure from conventional design when they were first introduced in 1934. They were built specifically to meet the needs of small communities, industrial plants and institutions. They can be operated by men without previous sewage experience. Since 1934, 200 Chicago "Pakage" Plants have been installed. All have excellent records for performance. None have failed.

Today, as then, "Pakage" Plants require a minimum of operating supervision, produce a sparkling clear effluent, are free from flies, foul odors, and unsightly appearance. They can be located near dwellings.

Initial cost is low. Operating costs are nominal.

Aeration and clarification are performed in a single tank with positive, automatic sludge control. One sludge setting covers a wide range of sewage flows and strengths.

Ingenious automatic features of Chicago "Pakage" Plants simplify operation and assure successful performance. Former farmers, salesmen, coal-miners and truck-drivers—without previous experience—are operating existing plants. Operator training service by Chicago Operating Sanitary Engineers is provided with each plant.

Specify Chicago "Pakage" Plants, proved by 16 years of successful performance.

Write for complete literature.

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Flush Kleen. Scru-Peller. Plunger. Horizontal and Vertical Non-Clogs Water Seal Pumping Units. Samplers.

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SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

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BUILDERS VISIBLE FLOW *Chlorinizers*

Builders Visible Flow Chlorinizers are designed to *simplify* plant operation — not to complicate it. Any competent mechanic with a knowledge of the proper methods of handling chlorine can easily master the operation and maintenance of Builders Chlorinizers. Specially trained personnel are not required to operate or service these chlorine gas feeders. The utmost safety and dependability are assured when Builders Chlorinizers handle your chlorination jobs. For Bulletins and complete information, address Builders-Providence, Inc. (Division of Builders Iron Foundry), 368 Harris Ave., Providence 1, R. I.

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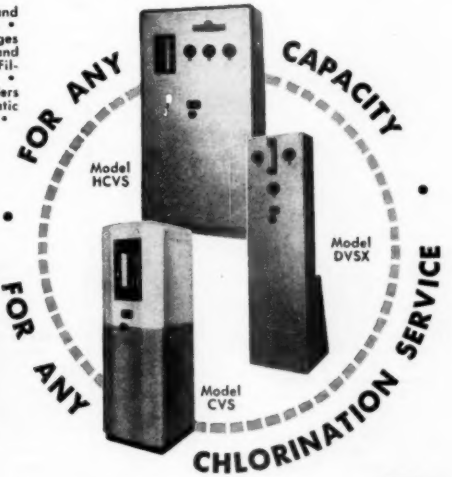
Installation in Sewage Plant, Medina, Pa.



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HOW TO MEASURE TRADE WASTES ACCURATELY

In accordance with anti-pollution laws recently enacted by numerous states, most industries now face the task of purifying their plant wastes before discharging them into adjacent streams and rivers.

This purification process usually requires special plant construction, and invariably the necessity exists of obtaining flow data, whether this be the simple indication of flow rate or a more permanent method of recording and totalizing the flow through the plant. With purification processes of this kind, measuring equipment usually is located at the point of discharge of partially filled pipe or in open channels, where low heads or pressures exist and where measurement is either difficult or impossible when using standard forms of measuring instruments.

The Simplex type S Parabolic flume, either alone or in conjunction with a Simplex type HF water float operated meter, is the ready answer to this measuring problem. Compact in design, with no pockets or grooves to catch sediment or solids, and capable of operating under low flow conditions, the unit measures over long ranges, from maximum to 5% of maximum capacity.

Available in standard pipe sizes of 6 inches to 36 inches diameter inclusive, the flume can be attached to even larger sizes by means of eccentric reducers.

Write for Bulletin 210, to the Simplex Valve & Meter Company, Dept. 4, 6719 Upland Street, Philadelphia 42, Pa.

IT'S SIMPLEX
IT'S ACCURATE

SIMPLEX
VALVE AND METER COMPANY

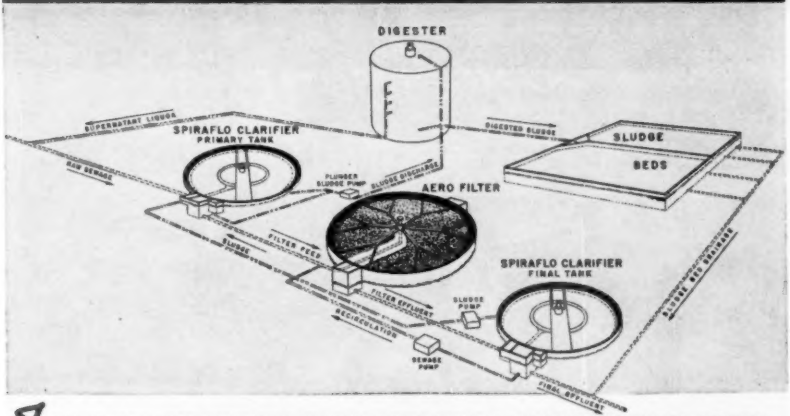
MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
California Sewage Works Association	Hotel Californian, Fresno, Calif.	Apr. 25–28, 1951
Pacific Northwest Sewage Works Association	Hotel Vancouver, Vancouver, B. C.	May 15–16, 1951
Maryland-Delaware Water and Sewerage Association	Commander Hotel, Ocean City, Md.	May 17–18, 1951
Michigan Sewage and Industrial Wastes Association	Hotel Pantlind, Grand Rapids, Mich.	June 4–6, 1951
New York Sewage and Industrial Wastes Association and New England Sewage Works Association	Springfield, Mass.	June 7–8, 1951
Alabama Water and Sewage Association	University of Ala., Tuscaloosa, Ala.	June 15, 1951
Institute of Sewage Purification	Buxton, England	June 18–22, 1951
Ohio Sewage and Industrial Wastes Treatment Conference	Neil House, Columbus, Ohio	June 20–21, 1951
Canadian Institute on Sewage Purification	Royal York Hotel, Toronto, Ont.	Aug. 20–22, 1951
Pennsylvania Sewage and Industrial Wastes Association	State College, Pa.	Aug. 22–24, 1951
Iowa Sewage Works Association	Hotel Tall Corn, Marshalltown, Iowa	Sept. 11–13, 1951
Kentucky–Tennessee Industrial Wastes and Sewage Works Association	Kentucky Hotel, Louisville, Ky.	Sept. 17–19, 1951
South Dakota Water and Sewage Works Conference	Charles Gurney Hotel, Yankton, S. Dak.	Sept. 19–21, 1951
Rocky Mountain Sewage Works Association	Cosmopolitan Hotel, Denver, Colo.	Sept. 26, 1951
North Dakota Water and Sewage Works Conference	Gardner Hotel, Fargo, N. Dak.	Sept. 26–28, 1951
Missouri Water and Sewerage Conference	Robidoux Hotel, St. Joseph, Mo.	Sept. 30–Oct. 2, 1951
West Virginia Sewage and Industrial Wastes Association	Daniel Boone Hotel, Charleston, W. Va.	Oct. 3–4, 1951

Federation of Sewage and Industrial Wastes Associations
Municipal Auditorium, St. Paul, Minn.
October 8–11, 1951

Florida Sewage and Industrial Wastes Association	The Princess Issena Hotel, Daytona Beach, Fla.	Oct. 28–31, 1951
New England Sewage Works Association	Sheraton-Biltmore Hotel, Providence, R. I.	Nov. 6–7, 1951
North Carolina Sewage and Industrial Wastes Association	Robert E. Lee Hotel, Winston-Salem, N. C.	Nov. 12–14, 1951

There's a YEOMANS Plant FOR EVERY WASTE TREATMENT NEED!



THIS LOW RATE, HIGH CAPACITY TRICKLING FILTER PLANT IS ESTABLISHING AMAZING RECORDS FOR HIGH PURIFICATION AT EXCEPTIONALLY LOW COST

These figures show a typical result produced by a Yeomans installation of the "Aero-Filter" and "Spiraflo" Clarifier in combination.

Overall plant efficiency is always higher when these units are used together. The method is especially effective for treating strong industrial wastes.

OPERATIONAL DATA . . . SPIRAFLO—AERO-FILTER PLANT *

1949 Date	Sewage Flow M.G.D.	Raw Sewage		Primary Effluent				Final Effluent				Overall Plant Reduction	
		Sus. Solids PPM	B.O.D. PPM	Sus. Solids PPM	Per Cent Reduction	B.O.D. PPM	Per Cent Reduction	Sus. Solids PPM	Per Cent Reduction	Per Cent PPM	Per Cent Reduction	Sus. Solids Per Cent	B.O.D. Per Cent
6-15	0.2996	210	255	79	62.4	136	46.6	28	64.6	18	86.8	86.6	93.0
6-16	0.2467	425	260	85	80.0	127	51.2	23	73.0	19	85.1	94.6	92.6
6-17	0.2554	410	235	124	69.7	141	40.0	28	77.4	18	87.3	93.3	92.4
6-18	0.2487	308	222	76	75.4	108	51.4	34	55.3	16	85.2	89.0	92.8
6-19	0.1753	222	218	64	71.2	132	39.5	17	73.5	—	—	92.4	—
6-20	0.2666	262	320	88	66.4	147	54.1	20	77.3	30	79.6	92.4	90.6
6-21	0.2279	240	215	78	67.5	138	35.8	19	75.7	20	85.7	92.0	90.7
Average	0.2456	297	247	85	70.5	132	45.5	24	71.0	20	85.0	91.5	92.0

* Name of plant furnished on request, as well as operating data from other installations.

"Spiraflo" Advantages

- Increased B.O.D. and settleable solids removal —influent is introduced tangentially into annular race around the periphery. Sewage spirals downward slowly and enters main clarification compartment at the bottom of the tank. Uniform, slow diffusion of waste under the skirt results in greatly reduced velocities and provides maximum removal of settleable solids.
- Greater removal of finely divided particles—due to upward flow through sludge blanket. This increases flocculation and results in more effective removal of finely divided particles before waste enters the effluent weirs.
- Straight-wall design minimizes construction costs.

"Aero-Filter" Advantages

- Thorough uniform distribution—therefore costly recirculation for dilution is unnecessary
- Operating cost is lowest of any type of complete sewage treatment
- Uninterrupted and almost complete momentary bed coverage minimizes troubles from odors, freezing, ponding, filter flies
- All returns made direct to the filter—no oversize primary tank required.

FOR INDUSTRIAL WASTES, TOO . . . Many types of industrial wastes can be successfully treated by direct application to the Aero-Filter without preliminary sedimentation.

Bulletins containing full details and helpful engineering data will be sent promptly upon request

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Please send these bulletins:
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City..... State.....

Storm Drains for Modern Expressways are Built of *CONCRETE PIPE*

THE CALUMET Expressway, a new highway entering Chicago from the south, will be drained by modern, economical concrete pipe. The drawing above shows a typical section.

In the drainage system water is collected at the pavement edges and channeled to catch basins located off both shoulders and under the median strip. From them the water is delivered to a single large-diameter concrete pipe near the center line.

Concrete pipe has been used for storm drains and sewers for more than a century. That experience has demonstrated that concrete pipe has long life and costs little or nothing to maintain. These factors, combined with its moderate first cost, add up to ***low-annual-cost*** drainage.

Concrete pipe has the strength to sustain heavy overburdens. Its smooth interior finish resists abrasion and provides maximum hydraulic capacity.

When planning a storm drainage system—or a sanitary sewer—specify concrete pipe for ***low-annual-cost*** service.

Photos show installation of concrete catch basin and 84-in. concrete pipe on Calumet Expressway. The size of the concrete pipe in this project ranges from 12 in. to 96 in. in diameter.

PORTLAND CEMENT ASSOCIATION

33 W. Grand Avenue • Chicago 10, Illinois

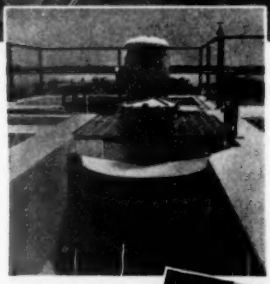
A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work

FOR EVERY STEP OF YOUR SEWAGE TREATMENT PROCESS

WHEN you specify INFILCO Sewage Treatment Equipment, you get more than just equipment. Actually, you specify over 50 years experience in the design and manufacture of a *complete range* of water, sewage and waste treatment equipment.

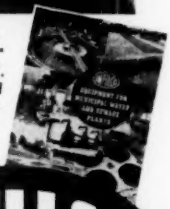
You have *one source* to depend upon for experience in both chemical and biological treatment ... for the major equipment items as well as the important control devices. And by providing a *complete range* of sewage treatment equipment INFILCO offers the all-important advantage of *undivided responsibility*.

A complete laboratory and staff of competent engineers are available for making recommendations and reports to the consulting engineer or his client. It is, of course, intended that this service shall cooperate with the work of your engineers. When considering your next sewage treatment plant, or the modernization of an existing one, call in your nearest INFILCO Field Engineer, or write our executive offices in Tucson.



SEND FOR..

Bulletin No. 60-C. It illustrates and describes many items of Infilco Equipment.



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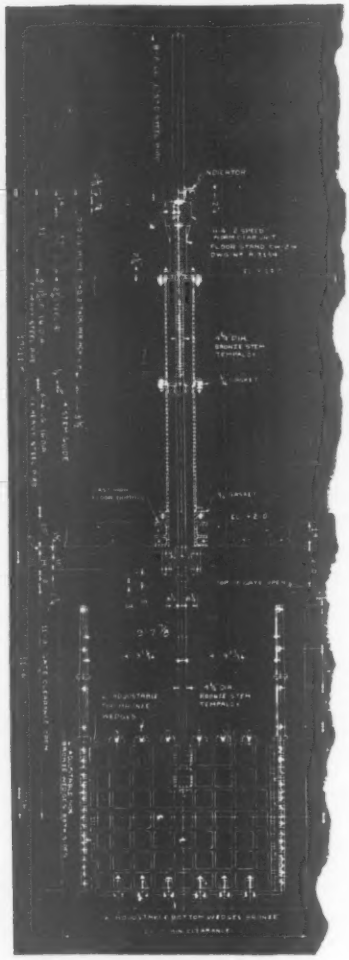
WORLD'S LEADING MANUFACTURERS OF WATER CONDITIONING AND WASTE TREATING EQUIPMENT

Designs from engineers' notebooks



Sluice Gate in EVERDUR

Designed and built by the Coldwell-Wilcox Division of Krajewski-Pesant Manufacturing Corporation, this inlet and control gate shows an economical use of special metals to give long life.

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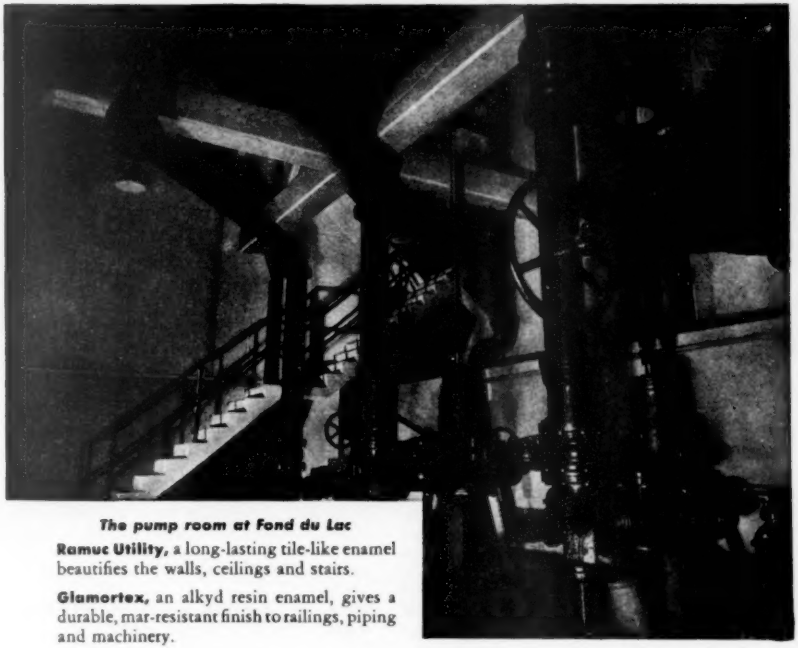

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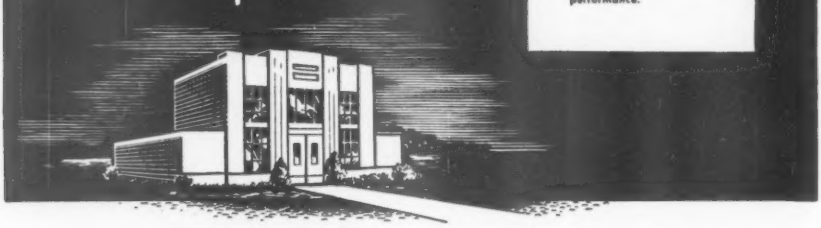

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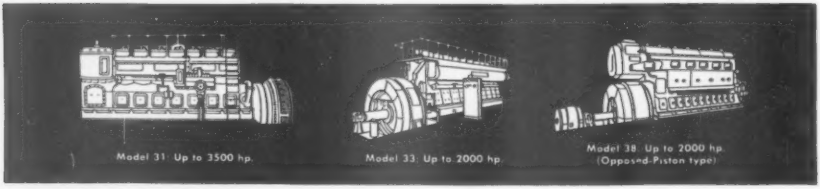

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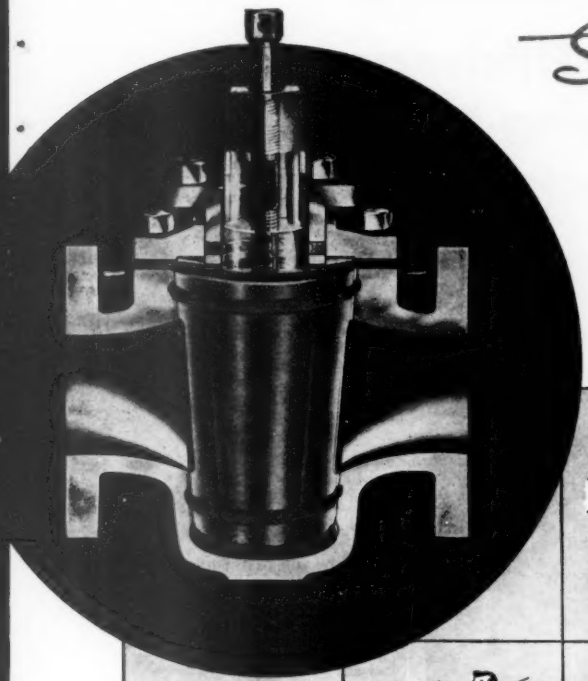

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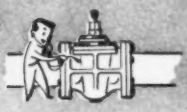

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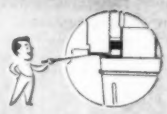

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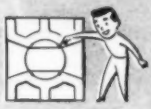

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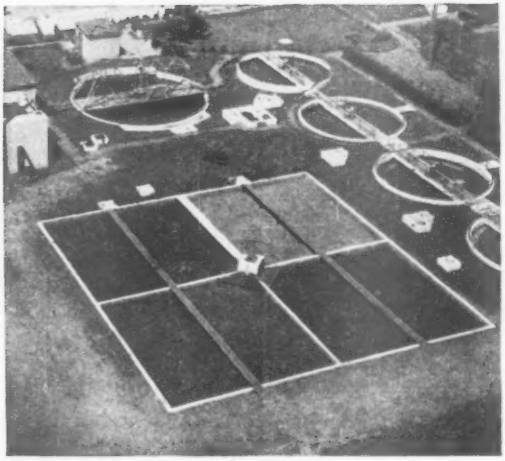

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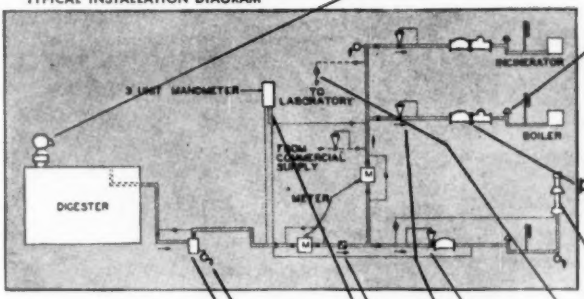

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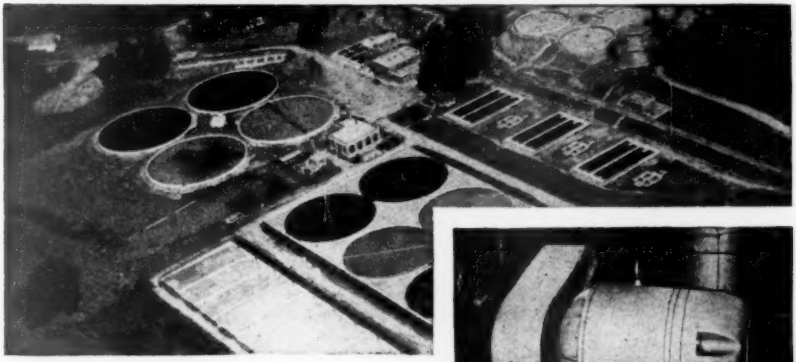

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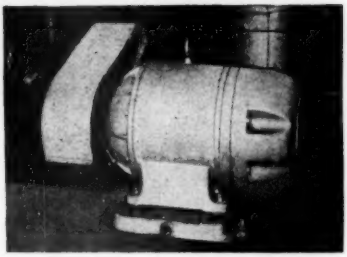

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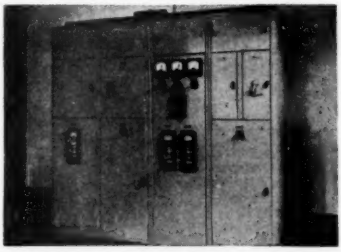

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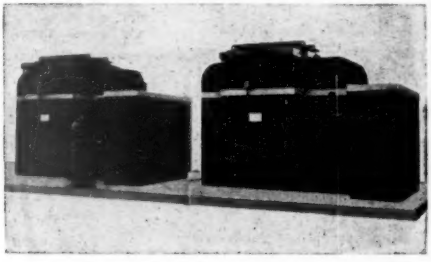

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Jeffrey Spiral Conveyor handling alum and lime in a large Water Works Plant. A section of Spiral flight is also shown.

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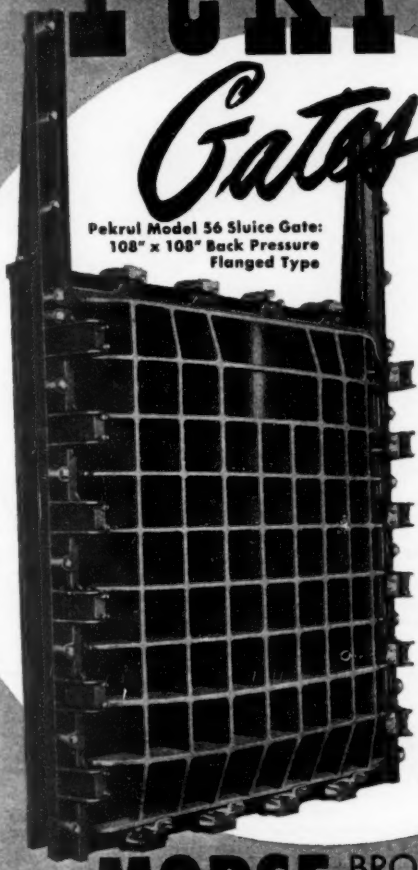

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 23 APRIL, 1951 Number 4

Contents

Sewage Works

Let's Look at the Record of Sanitation. By Gordon M. Fair 431

Alternating Double Filtration at Works of the Birmingham Tame and Rea District Drainage Board. By M. R. Vincent Daviss 437

Discussion by E. Sherman Chase 449

Design of Sewage Pumping Stations. By Richard R. Kennedy 451

Discussion by Grant M. Olewiler 460

Experience with Up-Sewer Cloroben Treatment in Southern California. By Richard Pomeroy 465

Discussion by Rolf Eliassen 474

Discussion by Herman Seydel and Albert H. Reiners 475

Contamination of Vegetables Grown in Polluted Soil. II. Field and Laboratory Studies on *Endamoeba* Cysts. By Willem Rudolfs, Lloyd L. Falk, and Robert A. Ragotzkie 478

Industrial Wastes

The Treatment of Penicillin Wastes. By David L. Muss 486

Adsorbents in Waste Water Treatment—Dye Adsorption and Recovery Studies. By H. A. Thornton and J. R. Moore 497

B.O.D. Determination of Trade Waste Samples in Admixture with Sewage. By W. E. Abbott and R. J. Fearn 505

Stream Pollution

Survey of Industrial Wastes in the Lake Huron-Lake Erie Section of the International Boundary Waters.

Part I. Introduction and Canadian Section. By A. E. Berry 508

Part II. United States Section. By H. H. Black and L. F. Oeming 517

Discussion by L. A. Danse 536

Discussion by A. D. McRae 537

The Operator's Corner

City Hall Relations 539

Settling Tank Weir Cleaner. By Floyd A. Gerard 540

1950 Operators' Forum 541

Tips and Quips 552

Proceedings of Member Association Meetings

North Carolina Sewage and Industrial Waste Association 146a

W. H. Wisely, *Editor*, 325 Illinois Building, Champaign, Illinois
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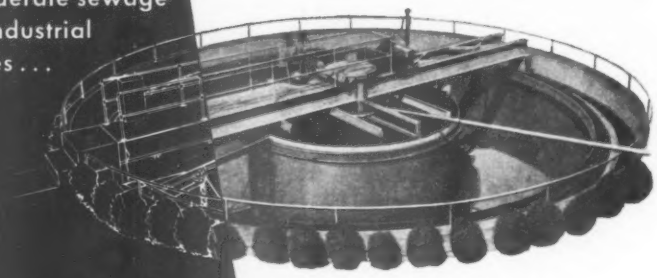
to preaerate sewage and industrial wastes . . .



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Sewage Works

LET'S LOOK AT THE RECORD OF SANITATION *

By Gordon M. Fair

Abbott and James Lawrence Professor of Engineering, and Gordon McKay Professor of Sanitary Engineering, Harvard University, Cambridge, Mass.

"Let's look at the record" may well be a motto for engineers, chemists, biologists, and administrators who are concerned with the sanitation of communities. The record of achievement is one of which they can be justly proud, but it is a record that is too little known and too little sounded. "A city set on a hill cannot be hid," but the sanitary works that serve the city, that bring it health and the comforts of civilized existence, are in large part buried in the ground "out of sight and out of mind." Where sanitation, and with it public health, flourish, the boon that it has conferred upon the community is tremendous, but it is quickly accepted and all too soon forgotten. The incidence of disease and death due to causes that have their origin in poor sanitation attains an almost irreducible minimum when the necessary elements of sanitation have been provided. Afterwards there appears to be little challenge or reason for enthusiasm, and only gross negligence or a calamity will call the attention of the public to the need for the activities of the sanitary engineering profession, which not only remain as great as before but increase as the number of nonimmunes in the population increases. For Hygeia is an exacting mistress who will not brook neglect.

If we would refresh our faith in the cause we serve, we need but turn back the pages of time and view the scenes that met the eye of that small group of enlightened men who looked both with understanding and with compassion upon the conditions under which large masses of people were forced to live less than a hundred years ago in the great communities of the world. Perhaps it will be best if we let these pioneers in sanitation present their case to us in their own words. Therefore, I quote freely from their writings or statements as given to us in publications of their day. Furthermore, no attempt is made to encompass the whole field of sanitation, these remarks being restricted to matters of sewerage and drainage, since these are the subjects in which my audience is particularly interested.

The Need for Sanitary Sewerage

The water carriage of wastes from household and industry, contrary to general belief, is only a little over a hundred years old. Early drainage works were built to carry away the runoff from storms. That they helped to cleanse the cities, at least superficially, of some of the communal debris, we can judge from descriptions such as that of a city shower of October, 1710, cased in the satire of Jonathan Swift.[1]

"Now from all parts the swelling kennels flow,
And bear their trophies with them as they go:
Filth of all hues and odour, seem to tell
What street they sail'd from, by their sight and smell.

* Presented at 1951 Annual Meeting, New York Sewage and Industrial Wastes Assn.; New York, N. Y.; January 19–20, 1951.

[1] First printed in *The Tatler*, No. 238.

They as each torrent drives with rapid force,
From Smithfield and St. Pulchre's shape their course,
And in huge confluence join'd at Snowhill ridge,
Fall from the conduit prone to Holborn bridge
Sweeping the butcher's stalls, dung, guts, and blood,
Drown'd puppies, stinking sprats, all drenched in mud,
Dead cats and turnip tops, come tumbling down the flood."

But the filth of the streets was of little importance, hygienically, compared with the filth of man's habitations. How great the need for sanitary sewerage had become as a result of urban growth during the nineteenth century is attested by reports from many sources. I shall record but a few. The first of these is taken from the "Report of the Poor Law Commissioners on an Inquiry into the Sanitary Condition of the Labouring Population of Great Britain" of 1842.[2] "Many dwellings of the poor are arranged," we are told in this report, "round narrow courts having no other opening to the main street than a narrow covered passage. In these courts there were several occupants, each of whom has accumulated a heap. In some cases, each of these heaps is piled up separately in the court, with a general receptacle in the middle for the drainage. In others a pit is dug in the middle of the court for the general use of all the occupants. In some the whole courts up to the very doors of the houses are covered with filth. Around this mass, the cottages of the residents are arranged, having no back outlet, no back windows, or other means of ventilation. The windows and doors of the houses are open and look towards this mass; and all the air supplied to the inmates is obtained through these doors and windows. The residents I learnt were very frequently subject to fever, and were always regarded as the first to be affected by any epidemic disease." And well they might.

A second report, also descriptive of London, is made in 1856 by the Medical Officer of Health in St. Olave's, Southwark.

"Here, within a small area, are thirty-nine houses, all having open foul privies, cesspools are filled, and many overflowing. The yards are foul, dirty, damp, and wretchedly paved with small, loose, broken bricks—most of them are daily filled with the overflowing of the drains and cesspools, the drains are all untrapped, and scarcely a house has a proper receptacle for water; they are mostly broken, dilapidated, uncovered tubs, placed close to the cesspools, so as to absorb the foul gases emanating from them. The effluvium on entering any of these places is abominable, and greatly complained of. . . ."

Of conditions such as these Charles Dickens had this to say at a public meeting in 1850:

"He knew of many places in London unsurpassed in the accumulated horrors of their long neglect by the *dirtiest* old spots in the *dirtiest* old towns under the *worst* old governments in Europe."

But we need not, in fact, go abroad for our "horrible examples." Two references to the City of New York should prove sufficiently shocking. Both are found in the "Report of the Council of Hygiene and Public Health of the Citizens' Association of New York upon the Sanitary Condition of the City," which was published in 1865. The first reference is to a statement of the medical inspector for the fourth inspection district.

"The number of inhabited basements and cellars is 224, occupied by 268 families, or about 1,400 persons. Their depth below the 'curb' or street level

[2] London, W. Clowes and Sons, "Local Reports," p. 2.

varies from 2 to 8 feet, averaging about 4½ feet.

"They are all damp, those in the least elevated localities, of course, being most so. In very many cases the vaults of privies are situated on the same or a higher level, and their contents frequently ooze through walls into the occupied apartments beside them. Fully one-fourth of these subterranean domiciles are pervaded by a most offensive odor from this source, and rendered exceedingly unwholesome as human habitations. These are the places in which we most frequently meet with typhoid fever and dysentery during the summer months."

The second reference is to the sixteenth inspection district.

"Location and care of Privies.—These form one of the chief features of insalubrity. Nearly all of them are too small in size and too few in number, and without ventilation or seat-covers. About twelve were found full to the floor timbers, or within one foot of them. In some cases the doors were found locked securely, and on procuring the key and inspecting the privy, such masses of human excrement were found on the seats and floors as would justify the locking of the door to protect unwary persons from injury. Occupants of rear buildings are the principal sufferers from this insalubrity. The proximity of privies is in some cases eight feet from the windows of rear houses; the odor in these is, especially at night, intolerable."

How the City of New York had fallen into so evil a state is told by Dr. Stephen Smith in "The City That Was."[3]

"Nature," says Dr. Smith, "had made ample provision for the metropolis of the western hemisphere . . . two large rivers of pure water from the mountains and the sea flushed its shores, carrying the outflow of its waste far away seaward; its soil could be thoroughly drained; its sewerage could be so constructed as to convey to the sea all forms of domestic waste and surface filth; its southern exposure towards the ocean insured sunlight and sea breezes; its inland situation supplied to its atmosphere the life-giving virtues of abundant vegetation; the climate was temperate."

Until 1866, however, according to Dr. Smith, "the people elected that the city should be unhealthy. The land was practically undrained; the drinking water was from shallow wells, befouled by street, stable, privy, and other filth; there were no adequate sewers to remove the accumulating waste; the streets were the receptacles of garbage; offensive trades were located among the dwellings; the natural water courses and springs were obstructed in the construction of streets and dwellings, thus causing soakage of large areas of land, and stagnant pools of polluted water.

"Later, in these centuries of neglect of sanitary precautions, came the immigrants from every nation of the world, representing for the most part the poorest and most ignorant class of their respective nationalities. This influx of people led to the construction of the tenement house by landowners, whose aim was to build so as to incur the least possible expense and accommodate the greatest possible number. In dark, unventilated, uninhabitable structures these wretched, persecuted people were herded together, in cellars and garrets, as well as in the body of the building, until New York had the largest population to a square acre (*sic*) of any civilized city.

"The people had not only chosen to conserve all the natural conditions unfavorable to health, but had steadily added unhygienic factors in their methods of developing the city.

"The result was inevitable. New York gradually became the natural

[3] Frank Allaben, New York, 1911, pp. 17, 18, 19.

home of every variety of contagious disease, and the favorite resort of foreign pestilences." The death rate in New York in the five years preceding 1866 averaged 38 per 1,000, which was 23 in excess of the standard of 15 per 1,000 which seemed to be obtainable in other "civilized" communities of the world at that time and perhaps 30 in excess of the expected mortality in similar age groupings today.

The recurrence of epidemic diseases such as typhoid fever, typhus fever, cholera, and even yellow fever, created among thoughtful medical men in New York a growing sentiment for reform. A society devoted expressly to sanitary reform, called The Sanitary Association, was organized and brought its case before the powerful Citizens' Association, which had been created in the early sixties under the presidency of Peter Cooper, the ironmaster, famous, among other things, for having built the first American locomotive and breaking up the notorious Tweed Ring. At a meeting of the Citizens' Association on February 29, 1864, the Sanitary Association was invited to become a Committee on Sanitary Inquiry of the Citizens' Association. In 1865 this Committee made its report, entitled "The Report of the Council on Hygiene and Public Health of the Citizens' Association of New York upon the Sanitary Condition of the City." It is this report that produced the sanitary reform of New York. Two of the quotations already given are taken from it.

The Need for Sewage Interception and Treatment

There was a sense of urgency in the sanitary reforms that highlight the second half of the nineteenth century, beginning with Edwin Chadwick in England in 1842, taking hold of the imagination of Lemuel Shattuck in Boston in 1850, and coming into force through Stephen Smith and his associates in New York in 1865. The removal of wastes from human habitations seemed to be particularly urgent. It could be and was brought about by calling existing storm drains into use. The combined system of sewerage was thereby created. As early as 1847, however, Sir Edwin Chadwick [4] had advocated the separate carriage of wastes from habitations and industries and of storm-water flows. His admonitions, unfortunately, fell on deaf ears. There would be less regret today if municipalities had accepted his advice of sending "the rainfall to the river and the sewage to the soil." With almost no attention paid to his warnings, it is only in the present century that the wisdom of separate systems of sewerage has been acknowledged through the efforts of health departments. In the intervening years, most established communities were forced to build great systems of marginal drains to intercept dry-weather flows from combined systems in order to give protection to water courses that had become overburdened with sewage.

Let us see how bad conditions had become before remedial interception was taken. Turning to the Thames we find in the *Lancet* of July, 1855, that the river presented the following aspect:

"The waters are swollen with the feculence of the myriads of living beings that dwell upon the banks, and with the waste of every manufacture that is too foul for utilisation. Wheresoever we go, whatsoever we eat or drink within the circle of London, we find tainted with the Thames. . . . No one having eyes, nose, or taste, can look upon the Thames and not be convinced that its waters are, year by year, and day by day, getting fouler and more pestilential. . . . The abominations, the corruptions we pour into the Thames, are not, as some falsely say, carried away into the sea. The sea rejects the

[4] Report of the Commission to Enquire into the Sanitary Condition of the Metropolis.

loathsome tribute, and heaves it back again with every flow. Here, in the heart of the doomed city, it accumulates and destroys."

Writing about this stream during the hot months of 1858 and 1859, Dr. Budd in his classical treatise on "Typhoid Fever, Its Nature, Mode of Spreading, and Prevention" had this to say:

"For the first time in the history of man, the sewage of nearly three millions of people had been brought to seethe and ferment under a burning sun, in one vast open *cloaca* lying in their midst.

"The result we all know. Stench so foul, we may well believe, had never before ascended to pollute this lower air. Never before, at least, had a stink risen to the height of an historic event. Even ancient fable failed to furnish figures adequate to convey a conception of its thrice Augean foulness. For many weeks, the atmosphere of Parliamentary Committee-rooms was only rendered barely tolerable by the suspension before every window, of blinds saturated with chloride of lime, and by the lavish use of this and other disinfectants. More than once, in spite of similar precautions, the law-courts were suddenly broken up by an insupportable invasion of the noxious vapor. The river steamers lost their accustomed traffic, and travellers, pressed for time, often made a circuit of many miles rather than cross one of the city bridges.

"For months together, the topic almost monopolised the public prints. Day after day, week after week, the *Times* teemed with letters filled with complaint, prophetic of calamity, or suggesting remedies. Here and there, a more than commonly passionate appeal shows how intensely the evil was felt by those who were condemned to dwell on the Stygian banks. At home and abroad, the state of the chief river was felt to be a national reproach. 'India is in revolt, and the Thames stinks,' were the two great facts coupled together by a distinguished foreign writer, to mark the climax of a national humiliation. But more significant still of the magnitude of the nuisance was the fact that five millions of money were cheerfully voted by a heavily taxed community to provide the means for its abatement. With the popular views as to the connection between epidemic disease and putrescent gases, this state of things naturally gave rise to the worst forebodings."

That there was no similar record for the waters that gird the City of New York is indubitably due to the large flow of upland waters carried by the Hudson River and by a majestic tidal prism. For Boston, however, Eliot C. Clarke's "Report on the Main Drainage Works of the City of Boston" (1885) quotes one of the Annual Reports of the Board of Health as saying:

"Complaints of bad odors have been made more frequently during the past year than ever before.

"They have come from nearly all parts of the city, but especially and seriously from the South and West Ends.

"Large territories have been at once, and frequently, enveloped in an atmosphere of stench so strong as to arouse the sleeping, terrify the weak, and nauseate and exasperate everybody.

"It has been noticed more in the evening and by night than during the day; although there is no time in the whole day when it may not come.

"It visits the rich and the poor alike. It fills the sick-chamber and the office. Distance seems to lend but little protection. It travels in a belt half-way across the city, and at that distance seems to have lost none of its potency, and, although its source is miles away, you feel sure it is directly at your feet. . . .

"The sewers and sewage flats in and about the city furnish nine-tenths of all the stenches complained of.

"They are much worse each succeeding year; they will be much more next year than this.

"The accumulation of sewage upon the flats and about the city has been, and is, rapidly increasing, until there is not probably a foot of mud in the river, in the basin, in the docks, or elsewhere in close proximity to the city, that is not fouled with sewage."

Chadwick's suggestion that sewage be carried to the soil underlies all methods of comprehensive sewage treatment. It implies in addition the utilization of the fertilizing constituents of the sewage. Although, in the course of time, we have learned to shun the direct use of sewage for the fertilizing of crops, because of the health hazards that are involved, we must acknowledge that the very attempt to carry sewage to agricultural lands has established sewage treatment as an essential component of sewage disposal. The thought of recovering useful elements from sewage was advocated, perhaps most eloquently by Victor Hugo in "Les Miserables." Recommending the employment of the sewage of Paris for the irrigation of farms along the Seine, Hugo wrote these rhapsodical lines:

"Paris casts twenty-five millions of francs annually into the sea; and we assert this without any metaphor. . . . Twenty-five millions are the most moderate of the approximate amounts given by the estimates of modern science. Science, after groping for a long time, knows now that the most fertilizing and effective of manures is human manure. . . . There is no guano comparable in fertility to the detritus of a capital, and a large city is the strongest of stercoraries. To employ the town in manuring the plain would be certain success; for if gold be dung, on the other hand our dung is gold. . . . Do you know what those piles of ordure are, collected at the corners of streets, those carts of mud carried off at night from the streets, the frightful barrels of the night-man, and the fetid streams of subterranean mud which the pavement conceals from you? All this is a flowering field, it is green grass, it is mint and thyme and sage; it is game, it is cattle, it is the satisfied lowing of heavy kine, at night it is perfumed hay, it is gilded wheat, it is bread on your table, it is warm blood in your veins, it is health, it is joy, it is life."

Although we may quarrel with these figures and these promises, we must admire the imaginative approach to the disposal of sewage that they present. You will agree with me, furthermore, that our predecessors were more colorful in their appeal for public support of needed sanitary ventures than we have dared to become in a more prosaic age.

May I close my recital of the record, as I began it, by letting a poet tell the story—in this case Samuel Taylor Coleridge after a visit to the City of Cologne in about 1798:

"The river Rhine, it is well known,
Doth wash your city of Cologne;
But tell me nymphs! What power divine
Shall henceforth wash the river Rhine?"

It is the duty of the sanitary engineer to mobilize this poetic, not to say prophetic, vision of a "power divine" that resides in our waters. Nature can, in fact, be made to marshal her powers to return the waste waters, if not to pristine purity, yet to a standard that meets modern health requirements.

ALTERNATING DOUBLE FILTRATION AT WORKS OF THE BIRMINGHAM TAME AND REA DISTRICT DRAINAGE BOARD *

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Historic Survey of Minworth Filter Beds

In a paper read in 1903, J. D. Watson, then engineer to the Birmingham Tame and Rea District Drainage Board, paid tribute to the experimental work on the bacterial treatment of sewage which had been carried out by the Massachusetts State Board of Health since 1887.

Nineteen years prior to this, in 1868, Edward Frankland had carried out in the laboratories of the Royal Commission on Pollution of Rivers, a series of experiments on the intermittent downward filtration of sewage through sand and various soils contained in glass cylinders 16 ft. and 6 ft. long. An account of this work is given in the First Report of the Rivers Pollution Commissioners (1870). On reading this report one is struck by the similarity of the apparatus used to present experimental filters, the Commissioners' appreciation of "the necessity for the continual aeration of the filtering medium" and the very low rate of filtration found necessary for the production of good results—a rate of something under 10 g.p.d.† per cubic yard. The report is of particular interest in Birmingham by reason of the fact that Dr. Frankland gave evidence before the House of Commons in support of the Birmingham Sewerage Bill in 1872. The works which were the subject of this Bill and which were designed by Messrs. Hawksley and Hope, included provision for the treatment of Birmingham sewage by intermittent downward filtration on the lines suggested by Dr. Frankland. Owing to opposition in Parliament the Bill was rejected.

In 1898 the Drainage Board, faced with an enormous capital outlay on land for extension of the existing irrigation area, sanctioned an expenditure of £ 1,000 for the construction of experimental artificial filters. Four filters of approximately 120-ft. diameter with mechanical distributors were constructed at Minworth. As a result of their satisfactory performance this system of treatment was adopted and the present filter bed installation at Minworth was developed.

It is interesting to note that the first blocks of filters were originally designed for double filtration with the primary beds smaller and dosed much more heavily than the secondary. It was stated that by so doing residual solids would be trapped in the primary filters, which were designed for ready cleaning, whereas the secondary filters would be less likely to clog up and no cleaning of them was envisaged. In fact, the secondary filter effluent was to discharge directly to the effluent channel without passing through humus tanks.

The arrangement as actually adopted, however, was single filtration with upward flow settling tanks for arresting the humus. Distribution on the early beds was by fixed jets located in the

* Presented at 23rd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Washington, D. C.; October 9–12, 1950.

† The Imperial gallon (= 1.2 U. S. gal.) is used throughout this paper.

soffits of mains laid on the surface of the bed medium.

More or less continuous extension of the filters was maintained until 1921, by which time 43 acres had been completed. No further filter beds have been constructed at Minworth since that date.

Measures to Increase Capacity of Existing Beds

The idea of stage treatment seems to have been firmly implanted in the minds of the Board's technical officers. The first development to increase the capacity of the main works at Minworth was the installation of bio-flocculation plants to give partial activated sludge treatment to a portion of the sewage. By providing a plant to give 1-hr. aeration it was found that the liquor could be satisfactorily treated on the beds at a rate 50 per cent greater than hitherto and that the condition of the beds was materially improved. Of the 40-m.g.d. dry weather flow received at the Minworth works at that time provision was made for giving partial treatment to 17 m.g.d.

Although the bio-flocculation process was thus adopted on quite an extensive scale, if in a somewhat unusual manner, the idea of double filtration still lurked in the minds of H. C. Whitehead, late engineer to the Birmingham Tame and Rea District Drainage Board, and F. R. O'Shaughnessy, late chemist to the Board. At their instigation a plant designed by them for alternating double filtration was operated by the Water Pollution Research Board at the sugar beet factory at Colwick, England, in the autumn of 1929.

The plant consisted of a primary filter, which was dosed with settling tank effluent at relatively high rates; primary humus tanks; pumps for returning the settled filter effluent to the secondary filter; and final humus tanks. Provision was made for reversing the order of operation of the two filters periodically with the object of preventing the development of excessive surface growths. The results of these experiments were not encouraging and were inconclusive, as the experiments were prematurely terminated by the close of the beet season.

A few years later, Mr. O'Shaughnessy was consulted privately with respect to three filters in Gloucestershire which were overloaded due to the discharge into the sewers of trade effluent from a vegetable packing factory. The filter installation consisted of three circular beds. On his advice the beds were operated in series—two as primary and one as secondary, each of the three being operated in rotation as secondary. The results in this case proved satisfactory, the success being due, almost certainly, to the high degree of purification effected in the primary filter effluent. At about this time full-scale experiments on the effect of recirculating effluent were being carried out at the Board's Yardley works. In 1934 the plant was installed at the Minworth works for returning filter bed effluent to the bed supply main at the rate of 13 m.g.d.

Between 1933 and 1938 the Water Pollution Research Board, of which H. C. Whitehead was a member, carried out laboratory and large-scale experiments on the treatment of waste water from dairies and milk product factories, including two-stage filtration, with periodic change in the order of the filters. The experiments proved that the system could be operated to give a satisfactory effluent from this difficult trade waste and also indicated that by its application the capacity of an existing bed installation could be materially increased.

As the result of cooperation between the Birmingham Tame and Rea District Drainage Board and the Water Pollution Research Board, full-scale experiments were commenced at Minworth in 1938, to compare the results of alternating double filtration and filtration with recirculation of filter effluent

ent with those from conventional single filtration.

The four experimental filters originally built by the Board in 1899 were reconditioned and equipped with new distributors, meters, humus tanks, and pumps to permit of their being operated in parallel, in series, or with recirculation. Furthermore, a laboratory was built on the site for the use of the Water Pollution Research Board, who have been responsible for the experiments carried out and the operation of the plant.

The filter beds in question are approximately 120 ft. in diameter and of depths varying from 6 to 7 ft. The filter medium consists generally of 1½- to 2-in. broken stone and pebbles. The filters are above ground level, three having walls of open stone, the fourth being brick construction. Each is equipped with a four-arm reaction distributor. Later, motor drive was installed on two machines so that the effect of varying the dosage interval could be observed. The experiments started by establishing the fact that all the beds gave similar results when operating under similar conditions and determining the maximum rate of dosage at single filtration, at which a satisfactory effluent was consistently obtained, and the surface of the bed showed no excessive ponding. This rate proved to be 60 g.p.d. per cubic yard of medium (equivalent to 203 lb. of B.O.D. applied per acre-foot per day). Experiments extending over several years were then carried out using various systems of filter operation. For one series, two of the beds were operated with alternating double filtration at varying rates of flow and with weekly, and later daily, interchange of the beds. For a period the primary effluent was fed without settlement to the secondary filter, but this proved unsatisfactory. In the early experiments, constant flow was maintained, but in later experiments it was varied at set periods three times a day so as to give a greater variation of flow than that normally received at the works.

Only effluents with a B.O.D. of less than 20 p.p.m. were regarded as satisfactory and in most cases the conditions for a given experiment were maintained for at least a year.

From the study of the Reports of the Water Pollution Research Board and papers published by members of the Water Pollution Research Board's staff, it was concluded that, by having double filtration with 24-hr. interchange of the primary and secondary filters, the Minworth settled sewage would give a consistently satisfactory effluent with a B.O.D. of less than 20 p.p.m. when dosed continuously at a rate not exceeding 250 g.p.d. per cubic yard of medium with settlement of the primary effluent. This over-all rate is calculated on the total volume of medium in primary and secondary filters together.

For design purposes, the figure adopted was 160 g.p.d. per cubic yard of total medium on the average dry weather flow, with a peak of 1.5 times the average—that is, 240 g.p.d. per cubic yard of medium.

Local Factors

The bulk of the storm water over most of the Board's drainage area drains into the sanitary sewers. Even with storm flows the sewage remains high in strength by normal standards. The dry-weather flow of sewage at Minworth is twice the dry-weather flow of the River Tame, into which the effluent is discharged. It is considered desirable, therefore, to give full treatment to all flows not exceeding 3 times the average dry-weather flow. However, because by alternating double filtration the filters are maintained in a highly active state, it is expected that for the relatively short periods of their duration, rates of flow between 1.5 and 3 times dry-weather average will be satisfactorily treated by single filtration only. Consequently, the design

allows for double filtration for flows up to 1.5 times the dry-weather average only, and at flows in excess of this the complete installation will operate with single filtration.

The dry-weather flow actually varies from 60 to 140 per cent of the average, so that it will be only during periods of storm that the system will revert to single filtration. The filter area will be divided equally between primary and secondary filters, with humus tanks for each stage. The distributors and the humus tanks serving each area will be designed for rates of flow equivalent to 1.5 times the average and will be working at maximum capacity on two occasions; namely, during maximum flow for double filtration (1.5 times the average passing through each half of the plant) and during maximum flow for single filtration (3 times the average passing through the complete plant).

The three main Birmingham sewers converge at the Board's Saltley works, where the sewage undergoes primary and secondary sedimentation in large rectangular tanks. From Saltley an 8-ft. diameter brick culvert 4.5 mi. long leads the settled sewage to the Minworth works, where part receives further settlement in upward flow tanks before being distributed on to the filters, and the remainder is given partial treatment in the bio-floeculation plants before passing to the filters. The 43-acre filter area, excluding the four experimental circular beds, comprises six blocks (Figure 1). Two of these blocks are now equipped with rectangular mechanical distributors; the remaining four are fed by fixed jets. The filter effluent is settled in upward flow humus tanks before passing to the River Tame.

The conversion of the entire works has been planned in definite stages correlated to the abandonment of obsolete preliminary treatment works at Saltley, Ashold, and Tyburn and the concentration of the complete treatment plant at Minworth. The first stage includes reconstruction of Block

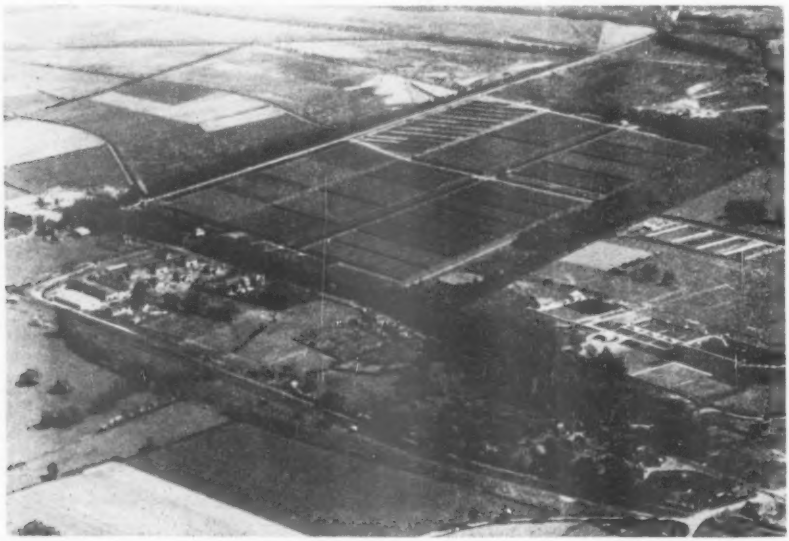


FIGURE 1.—Aerial view of Minworth filter beds. Eight beds comprising Block A in near corner of filter area; four circular experimental beds immediately adjacent.

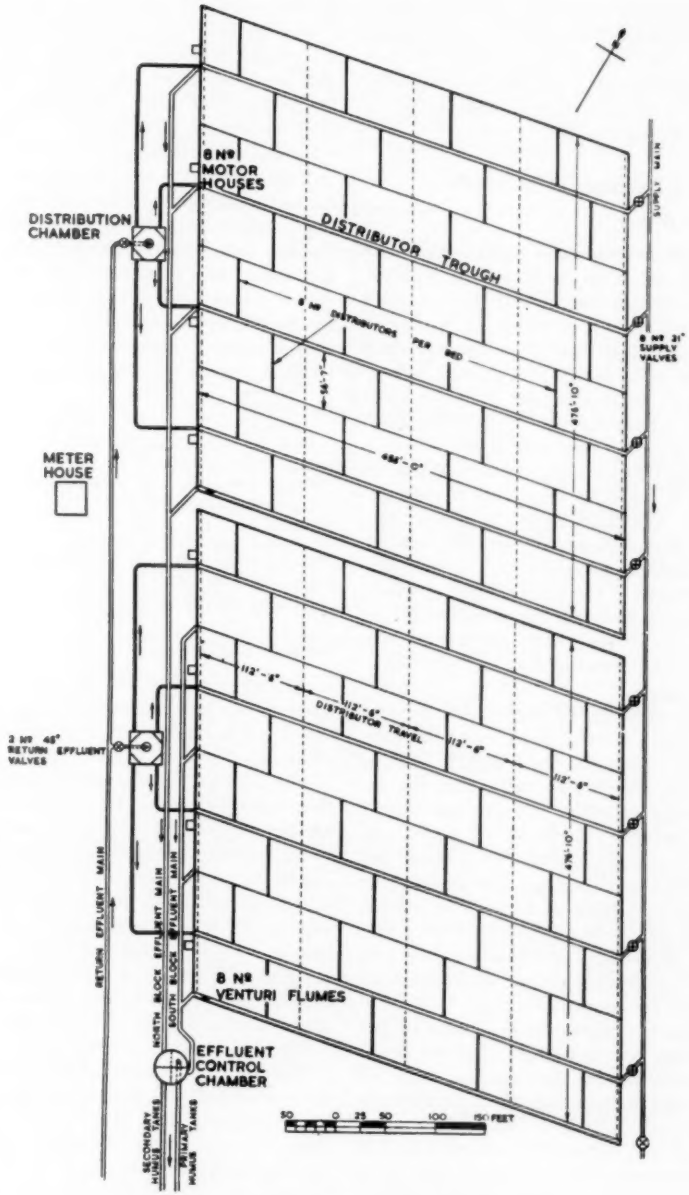


FIGURE 2.—Layout of new Block A filter beds.

A, the oldest of the six blocks of filter beds, and construction of four humus tanks, two for primary and two for secondary stage, a humus sludge pumphouse, a return effluent pumphouse, a meter house, motor houses, etc.

Description of Works

Filter Beds

Block A consists of eight separate 1-acre beds. The beds are of conventional British design with 6-in. sloping concrete floors covered with closely packed glazed floor tiles and approximately 6-ft. depth of medium, generally 1-in. to 2-in. in size, but with some areas of finer material. The individual filter beds are irregular in shape (Figure 2), having been constructed to fit in with the road layout as it then existed. Distribution is by fixed jets. The effluent is passed through heavily overloaded, upward flow humus settling tanks to the main effluent conduit. The reconstruction involves the filling up of six of the roadways between the beds, thus forming two large blocks—the "north" block and the "south" block—of about 4.4 acres each, the construction of reinforced concrete gantries carrying the eight supply troughs and the distributor rails, and the installation of eight sets of rope-hauled distributors. Each set of eight machines will be driven by a 5-hp. reversing electric motor. The distributor will have a span of 56 ft. 7 in. and a length of travel of 112 ft. 6 in. The speed is specified as 40 ft. per min. and the distribution from each machine will be continuous.

With the fixed jets the shape of the bed was not important, but to equip a parallelogram having an angle of 72° × 04′ with rope-hauled distributors is difficult. That a satisfactory solution of this difficulty has been found is demonstrated by the fact that few visitors, viewing a similar area mechanised in 1937, remark on the fact that all the machines are built on the skew.

The present supply to the beds is by a main along the east side and the new work includes installation of 21-in. connections with electrically operated valves to each of the 8 supply troughs. Eventually, when the new outfall works have been constructed on a site to the west of the beds, the primary supply will be fed from that side via the distribution chamber. In the meantime, this chamber will be used only for supply of settled effluent from the primary filters to those operating as secondary. Design details for the Block A installation are as follows:

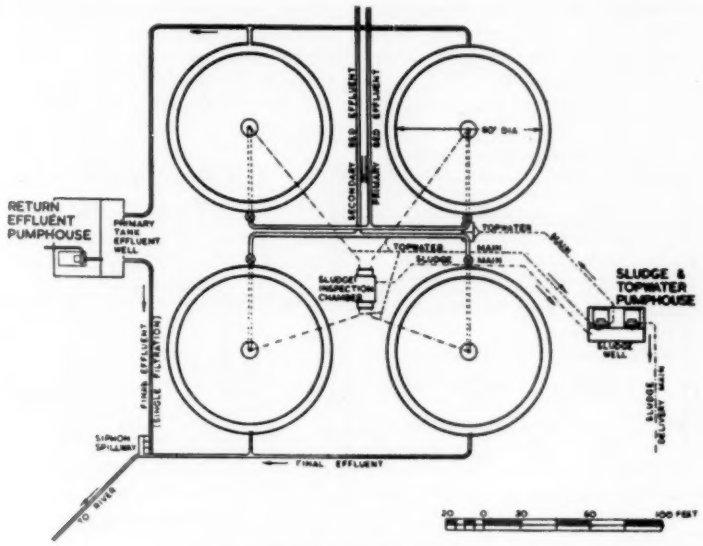
Flow (m.g.d.):	
Average	14.4
Max. at double filtration	21.6
Max. at single filtration	43.2
Volume of medium (cu. yd.)	86,000
Volume of medium (acre-ft.)	53.3
Loading:	
Primary bed (g.p.d./cu. yd.)	334
Primary bed (lb. B.O.D./acre-ft./day)	1,130
Over-all (g.p.d./cu. yd.)	167
Over-all (lb. B.O.D./acre-ft./day)	565

Humus Tanks

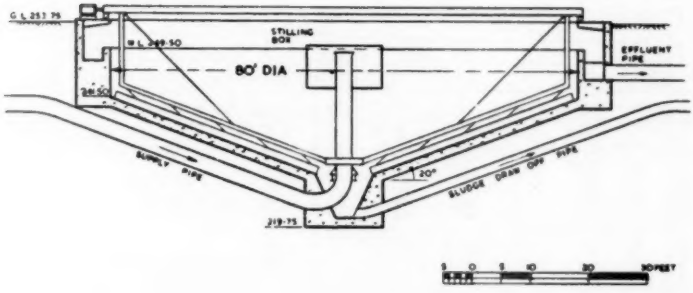
As the existing humus tanks are overloaded, new tanks are being provided for both primary and secondary effluents.

The four new tanks are to be radial flow circular tanks, 80 ft. inside diameter, with a continuous peripheral weir, an 8-ft. vertical wall, floor sloping at 20° to the horizontal and central sludge pocket 10 ft. in diameter at the top, 2 ft. 6 in. in diameter at the bottom, and 7 ft. 6 in. deep. The supply will be by a 33-in. diameter cast-iron main laid under the floor and carried up centrally to discharge at a point 6 in. below the water level. The inflow will be diverted downwards by a circular baffle 13 ft. 6 in. in diameter and extending 5 ft. 6 in. below water level. The floor of the tank will be continuously swept by four blades supported by an 80-ft. diameter rack driven by 1.75-hp. electric motor.

The rollers carrying the rack will be supported on cantilever brackets from the tank wall, thereby making it possible to sweep the weirs and effluent channel with blades carried out from the vertical members of the scraper mechanism. The sludge will be discharged under hydrostatic head from the sludge pocket of each tank through a 15-in. diameter main to an inspection and gaging chamber, from which it will flow to the sludge well and pumphouse. Provision is made for by-passing the inspection chamber so that the pump



LAYOUT OF HUMUS TANKS



SECTION OF HUMUS TANK

FIGURE 3.

can draw directly from the tank. The humus tanks are designed for a maximum upward velocity of 8 ft. per hour.

Humus Sludge and Top-Water Pumphouse

The sludge pumphouse is a reinforced concrete structure integral with the sludge well. It is of such depth that the pumps are below working sludge level in the well. It is large enough to accommodate pumps to serve eight tanks; only those required for four tanks will be installed in the first instance. The pumps are to be of the horizontal spindle, center inlet centrifugal type directly coupled to electric motors. The present installation is to consist of one 8-in. manually controlled, variable speed pump for top water; one 8-in. manually controlled, variable speed pump for top water or sludge; and one 8-in. float controlled, variable speed pump for sludge. Each will have a capacity of 1,000 to 500

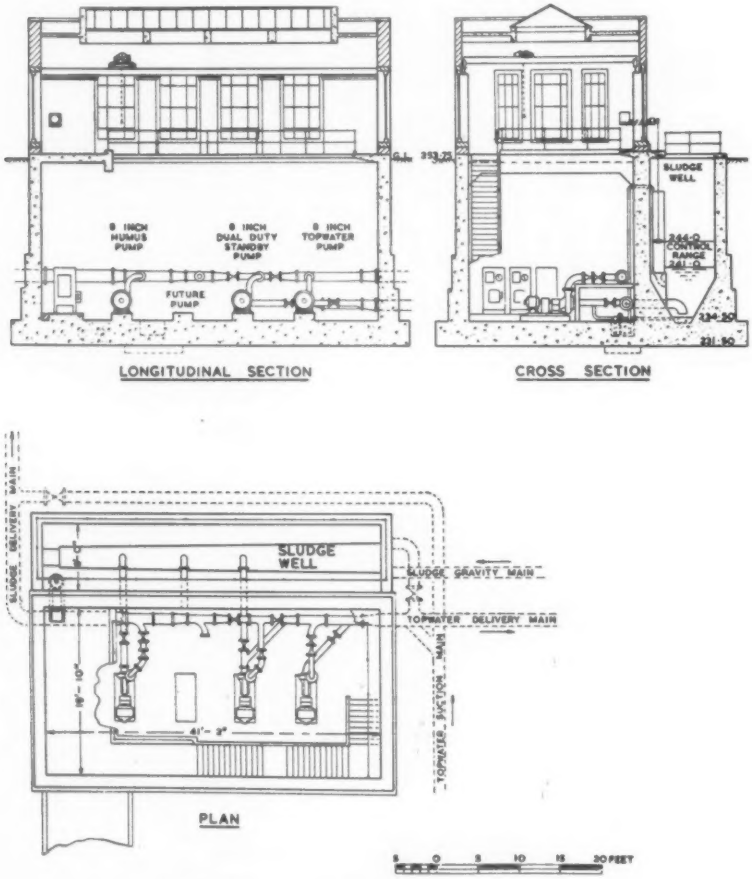


FIGURE 4.—Sludge and top-water pumphouse.

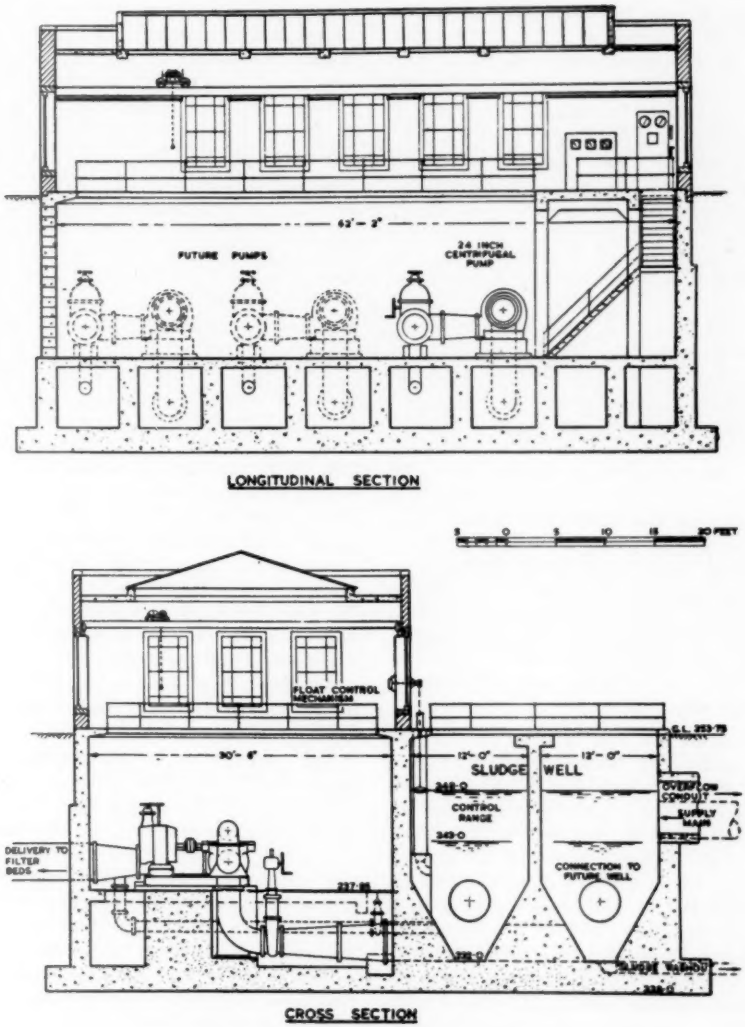


FIGURE 5.—Returned effluent pumphouse.

g.p.m. It is anticipated that sludge will be withdrawn continuosuly.

Return Effluent Pumphouse and Well

The effluent from the two primary humus tanks will flow by gravity to the return effluent well, from which a siphon overflow will discharge to the main effluent channel. The pumphouse basement will be integral with the well (Figure 5), but will have the north end built up in precast beams to facilitate future extensions, the present structure being designed to accommo-

date pumps for only three of the six blocks of beds.

At first there will be only one 24-in. float-controlled, variable speed pump of capacity varying from 15,000 to 3,000 g.p.m. No stand-by pump is being provided, as in times of emergency single filtration can be operated satisfactorily for the limited periods required to replace the pump assembly, of which a spare will be held in the Board's stores.

Power

Power for the distributors, scrapers, and all pumps will be taken from the private power loop supplied from the Board's existing generating station at Saltley, until new digestion tanks and a new generating station are constructed as part of the proposed new works at Minworth. The speed variation of the 35-hp. a.c. motors for the sludge pumps will be effected by rotor resistance, but for the return effluent pump a mercury arc rectifier will be used to supply the 180-hp. variable speed d.c. motor.

Metering and Operation

As meters will be required for the primary and secondary flow to each of the eight beds and as the available head on the supply system from the east end of the bed is strictly limited, it was decided to install a Venturi flume in each of the eight bed effluent channels. A direct-reading float-operated indicator will be sited at each flume. These will transmit the rate of flow to the main instrument panel, on which will be remote indicators, with both a primary and a secondary recorder and integrator to each flume. The panel will also house push-button controls for the eight 21-in. supply valves, the two 45-in. return effluent valves, and the gate in the effluent control chamber. When a bed is operating as primary stage, the "primary" recorder and integrator will be functioning. When the bed operation is changed to secondary, a control switch will cut out the "primary" instruments and bring in the "secondary." Primary and secondary recorders will both register on the same chart to left and right, respectively, of the center line, so that the chart will be a complete record of the bed operation. The integrators will give separate totals for the volumes treated on the bed while operating as primary and as secondary stages. During periods of single filtration the instruments will record as for "primary" stage.

The effluent from each block of four beds will be led by independent mains to the effluent control chamber where it will be diverted to the appropriate pair of humus tanks. From the two primary humus tanks the effluent will flow to the return effluent pump well, from which it will be delivered by pump to the appropriate distribution chamber. Four 8-ft. weirs in each of the two distribution chambers will insure equal distribution to the four supply troughs on the beds.

The two secondary humus tanks will discharge directly to the main effluent conduit.

The capacity of the return effluent pump will be adjusted to the sewage flow automatically by the float control up to the maximum rate of 1½ times the average flow. When the rate of flow increases above this, the float control will put the pump out of operation, and sound a warning bell to the attendant. As the pump well fills, the siphon overflow will come into operation and the settled bed effluent will pass to the main effluent conduit. The four supply valves on what were the secondary beds will be opened and the plant will then operate on single filtration.

When a falling rate of flow reaches 1½ times the dry weather flow the meters will operate a minimum flow alarm. The four supply valves will then be shut and the return effluent

FIGURE 6.—General view of humus tank installation under construction.

pump brought into operation manually; the system will thereby revert to double filtration.

One consideration in the design of an alternating double filtration plant on the scale of the Birmingham installation, is the attendance involved in the operation of a number of large valves at least once every 24 hr. This difficulty has been met partly by the obvious, but expensive, provision of electrically operated valves, and partly by the gate device in the effluent control chamber, known as the Zboinski chamber after the staff member who introduced the idea.

This chamber takes the place of four 39-in. diameter valves. In essentials it is circular in plan with four pipe connections equally spaced around the circumference. Two opposite connections supply effluent from the "north" and "south" blocks, respectively, and the other two deliver to the primary and secondary humus tanks, respectively. By suitable positioning of a gate rotating about the axis of the chamber the effluent from the north block can be directed to either the primary or secondary humus tanks, and that from the south block will then be directed to its corresponding tanks.

Complete automatic control was seriously considered. Although very attractive in theory, in other applications it has not proved to be so in practice. Consequently, it was not adopted for this installation.

Discussion

That alternating double filtration is most suitable for the conditions at the Board's Minworth works is a conviction based on extensive experimental evidence and continuous operational experience over a period of 12 years.

Recirculation has much to recommend it: it requires less attention, is simpler in operation, and a little lower in capital cost. At Minworth, however, filters operating on recirculation do not maintain as good a condition as those on alternating double filtration.

Mechanical aeration processes are possible either as complete or partial treatment plants. Experiments have proved that the Minworth sewage can be treated to give a satisfactory effluent, but the period for aeration is considerably prolonged beyond the

TABLE I.—Typical Analyses (p.p.m.)

	Susp. Solids	B.O.D.	Oxygen Absorbed	Ammoniacal Nitrogen	Oxidized Nitrogen
Raw sewage	563	330	190	40	—
Settled sewage to filters	130	210	100	40	—
Primary filter effluent: [1]					
Shaken	40 to 70	—	—	—	—
Settled	10 to 20	40	25	35	5
Secondary filter effluent: [1]					
Shaken	35 to 60	—	—	—	—
Settled	10 to 20	20	15	25	15

[1] Design expectation.

normal. Partial treatment has been usefully employed for many years by the Board but this method, particularly at the Yardley works, has shown itself to be susceptible to damage from flushes of acid and metallic trade wastes. Furthermore, it has been proved that the total annual cost of either system would be greater than for the system which will be adopted using existing filter beds.

The large volume of industrial effluents from the metal industries gives rise to particular problems in treating the Minworth sewage. Out of seventy-six requests received from manufacturers for permission to discharge industrial effluents into the sewers, sixty-two were from processes involving the use of mineral acids, cyanides, chromium, copper, nickel, or cadmium salts.

From the typical analyses (Table I), it will be noted that the B.O.D. of the Minworth tank effluent supplied to the filters is not high. This, however, is no indication of its treatability.

The small Barston works of the Board receives a sewage that is almost entirely domestic in origin. This sewage often has a B.O.D. not differing greatly from that of the main flow of sewage, which is eventually treated at Minworth works. An effluent of first-class quality is obtained from the filters at Barston with a dosage of 120 g.p.d. per cubic yard, whereas from the filters at the Minworth works an inferior effluent is obtained at a dosage of only 60 g.p.d. per cubic yard.

A significant figure seems to be the ratio of the B.O.D. to the oxygen absorbed from acid permanganate in 4 hr. at 27° C.

For the Barston sewage this ratio is about 4:1, but in the raw sewage, which is later treated at Minworth, the ratio is about 2:1. The permanganate figure is thus a partial measure of the strength of industrial effluents, but there may be present in the sewage other inhibiting substances not measured by the ordinary methods of analysis.

With single filtration at Minworth the factor limiting the rate of treatment is the accumulation of fibrous growth on the surface of the filter. With alternating double filtration this growth develops on the primary bed, even with the relatively high rate of application. However, when the filter is used for the secondary stage, growth is arrested and disintegration occurs.

The experiments indicated that with alternating double filtration the discharge of humus sludge is uniform throughout the year and there is not the spring discharge so characteristic of conventional single filtration plants. Also, over a 12-month period the weight of humus discharged, per million gallons of sewage treated, was slightly greater from the double filters than from the single filters.

Stress has been laid on the fact that for satisfactory operation of alternating double filtration a critical degree of purification must be obtained in the primary treatment so that the secondary beds may receive a liquor which will starve and scour the fibrous growth rather than feed it. It appears that at Minworth the primary effluent should have a B.O.D. of less than 40 p.p.m.

The design of the plant has been carried out entirely by the engineer's staff and is the result of very whole-hearted cooperation of civil, electrical and mechanical engineers; chemists; and the outside staff, who will eventually have the operation of the plant.

The construction work is being carried out by direct labor. Had the requisite labor been available the plant would have been already in full operation, but, with the limited force, progress is slow. The development program of the Board is now many years in arrears. As each section of the work is completed it will be brought into immediate use. Thus, provision is being made to bring the humus tanks, now nearing completion (Figure 6), into use for the betterment of the general effluent, as it will be some time before the conversion of the bacteria beds is complete.

Acknowledgments

Sincere thanks are extended to the chairman and members of the Birmingham Tame and Rea District Drainage Board and to F. C. Vokes, engineer to the Board, for granting facilities for the preparation and presentation of this paper. Thanks are also given to S. H. Jenkins, R. E. F. Gardner, and other members of the staff who have given invaluable help and much candid but constructive criticism.

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DISCUSSION

By E. Sherman Chase

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It is particularly pleasing to discuss Mr. Daviss's paper for personal as well as professional reasons. Years ago the writer carried on somewhat limited correspondence with the late John D. Watson, then chief engineer of the Board, regarding trickling filter operating experiences. Subsequently, an opportunity was afforded to visit the Birmingham works at the time when the late Mr. Whitehead was chief engineer.

Mr. Daviss's paper is of definite interest in the United States, because it describes a method of operating trickling filters not as yet adopted anywhere in this country so far as is known. Although two-stage filters using recirculation and without alternate operation as primary and secondary units are

in use. The advantages of this alternate function appear to be in the prevention of overdevelopment of filter slimes, the continuous unloading of the filters, and the uniform loading of the humus tanks.

Another advantage, in the case of sewage carrying large amounts of industrial wastes, as at Birmingham, seems to be the shock absorbing effect of the primary filter as with any two-stage process, but with the opportunity for the shocked filter to be given a chance to recuperate. In this connection it is interesting to note that the thinking at Birmingham has apparently come around to the view that trickling filters are better than bio-flocculation for absorbing the shock from heavy concentrations of industrial wastes. This present thinking is more in line with German and American viewpoints than with that of Mr. Whitehead when he installed the bio-flocculation units ahead of the old trickling filters.

The B.O.D. loading for which the new Birmingham filters are designed is low compared with the loadings used in the United States with high-rate filters using recirculation. The loading is, however, comparable with standard-rate filter loadings here. It should be noted that the Birmingham sewage is stronger than most American sewages and that the final effluent is expected to be highly nitrified and to have not over 20 p.p.m. of B.O.D. Furthermore, the industrial wastes factor at Birmingham must not be overlooked.

The question comes up as to whether the anticipated high nitrate content of the effluent is likely to produce objectionably luxuriant growth of microscopic organisms and aquatic plants in the receiving stream. Sometimes it doesn't pay to produce too good an effluent, as was evidenced at Brockton, Mass., where a well-purified effluent so stimulated aquatic growths as to choke the receiving brook, resulting in lawsuits and substantial damage payments to lower riparian owners.

One criticism that can be made of the old Minworth filters relates to the poor distribution effected by the fixed spray nozzles on some of the beds. Photographs taken in the summer of 1950 confirm the writer's recollection that the beds provided with fixed nozzles are dosed very inefficiently. On the other hand, it was observed that the humus tanks with the central feed as described, produce excellent clarification.

In conclusion it is desired to emphasize the large scale of the experimental tests and the long period of time over which they were conducted. Too frequently pilot plants have to be operated on very small scales and for much too short periods of time. The results from such large-scale and long continued experimental tests, as carried out at Birmingham, can be applied by the designing engineer with a comfortable feeling of assurance that the completed plant will function as planned.

DESIGN OF SEWAGE PUMPING STATIONS *

By Richard R. Kennedy

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This paper presents some of the problems involved in the rational design of a sewage pumping station, together with some of the special requirements or design features found to give a properly functioning and easily operated sewage pumping station.

Nearly every present sewerage system development or improvement involves sewage pumping. This is particularly true in the West Coast area.

Historically, most of the major cities of the Pacific Coast were originally settled in areas adjacent to ocean transportation. As the cities developed the drainage systems and, later, sewerage systems were installed so that the discharge from these systems was into the nearest salt-water basin. With the growth of the cities, additional outlets or points of discharge were installed as required. The topography of the area is generally favorable to such a system of development.

With the present rapid increase in population throughout the Pacific Coast area, the discharge of raw sewage to the ocean, bays, and rivers is no longer being tolerated. The collection of multiple outfalls by intercepting trunk lines to convey the sewage to central locations for treatment generally requires the installation of additional pumping stations. Much of the development in the immediate postwar period has been in the so-called low-cost housing field constructed by speculative builders.

The land incorporated in such a project is completely developed within a few months time, so that a whole community comes into being seemingly overnight. The land chosen for the development is usually selected because there is a satisfactory area of undeveloped property available. This property is always beyond a developed sewerage system and generally outside a developed sewerage system drainage area. In the San Francisco Bay area, many housing developments are located on lands adjacent to the Bay. Many of the areas have required filling to bring the ground surface above high tide level.

In discussing sewage and sewage treatment with the layman, use is quite often made of the definition of sewage as "the water-borne wastes of a community which, under average conditions in this country, contains 99.8 per cent water, with 0.2 per cent of mineral and organic wastes requiring treatment." Whereas, in theory, sewage pumping should be no more difficult than any other water pumping problem, those who have had any experience with sewage works know that although the percentage of contaminant is small, the problems in handling sewage are manifold. Sewage differs from a water supply physically, biologically, and chemically—physically due to floating and suspended material of small to large size; biologically due to the organic wastes, most of which are highly putrescible; chemically due to the organic and mineral wastes in solution.

Sewage pumping stations are expensive to construct and operate. It is, therefore, important to construct a

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sewerage system to reduce the volume of sewage to be pumped to a minimum or to combine the pumping stations for maximum economy in construction cost or operation.

Location

The first consideration in the design of a sewage pumping station is its location in the flow layout of the system. The station may be a small unit serving a very limited drainage area where the sewers have become too deep for economical construction, or the location may be fixed to take the sewage from a local drainage area into the mains flowing in some other direction. The flows to be cared for and the pump heads for such a plant usually constitute a simple problem. The main consideration for such a pumping plant is freedom from maintenance problems and low cost of construction. It is sometimes possible to extend the gravity mains from the system receiving the flow from such a plant at a shallower depth than would be acceptable for house service in order that the pump lines from the pump discharge can be as short as possible. Because the sewage deteriorates rapidly in closed pressure pipe, it is very important to keep pump discharge lines short. This is particulary important in small stations where there may be long periods during the low flow time when sewage may not be flowing in the pipes.

If the pump station is constructed in connection with the treatment plant it may have several locations within the flow layout. It may be at the head end of the plant as the sewage first arrives; it may be installed following grit removal; or between any of the subsequent treatment units.

Assuming that a treatment plant will require pumping of the sewage somewhere within its operation, many problems can be avoided by selection of the location of the pumping units in the flow layout. The pump location must be selected in conjunction with the arrangement of structures and after careful consideration of excavation costs and drainage problems involved in the other treatment plant units.

If the pumping is done after sedimentation the problem of pump stoppage from refuse and the problem of floating grease or other materials will be greatly reduced. The peaks of flow to be cared for by the pumping units will be leveled out to a considerable degree if preceded by sedimentation.

If the pumps are installed following grit removal the problem of grit wear on the pumps and settlement in the pump sumps has been eliminated; however, there is still the problem of floating materials and fluctuation of flow to be considered.

If the pumps are installed as the first unit in the treatment plant arrangement, all of the problems involved in sewage pumping are present; namely, grit being carried in the sewage flow, floating material on the surface, and the possibility of large-size refuse that might cause pump stoppage.

Quantity and Head

After the pumping station is located in relation to the flow sheet, it is possible to set up the head to be met and the quantity of sewage flow that must be cared for, based on the assumed design requirements for the plant or system. The pumping station should be considered as a unit of the sewage collection system and should be designed to take care of the maximum expected flows of the pipe system. This does not mean that it must necessarily all be constructed initially, but it should be planned so that future expansion may be made. The present minimum flows should be fully determined. The present maximum flows, for which immediate provision must be made, should be estimated as accurately as possible. For a small pumping station the storage capacity in the sumps depends on the inflow during periods of low flow. The sumps

should have storage capacity sufficient to operate one pump for a period of at least 10 minutes. As the size of the plant increases it is possible to reduce the pump storage in terms of flow periods so that one pump will operate continuously and additional units will go into operation as the flow increases.

In conjunction with the total quantities to be pumped, it is necessary to determine the elevation at which the sewage will be discharged. In the case of a discharge to a plant structure the discharge elevation is usually very constant. However, if the discharge is into a tidal body of water, or into water subject to flood conditions, the variation in water surface may be considerable. It is well to have in mind that sewage pumping stations operate at comparatively low heads and any appreciable variation in the inlet elevation or discharge elevation will materially change the head conditions for which a pump may have been selected and, as a consequence, the discharge of the pumping unit will be materially affected.

Types of Pumps

In most pumping problems the selection of pumping units is a simple matter after the head and quantity have been determined. However, in sewage pumping stations the selection of the pumps is a problem even after the determination of the quantity and head conditions.

Manufacturers have developed special centrifugal pumps for sewage pumping. The special features include open or specially shaped impellers to provide non-clog characteristics, cleanout openings, slow speed, and grit and corrosion resistant construction. Setting forth and discussing detail specifications for sewage pumps is a subject for an entire paper and beyond the scope of this presentation.

Sewage treatment plants or pumping stations receive the wastes of the community when and as they occur. An ideal pumping setup would be so arranged that the quantity of discharge would vary in direct relationship to the inflow of the pump sump. There have been many devices and arrangements developed or installed in an attempt to meet this requirement. Installations have incorporated variable speed pumps, in which the speed of the pump is increased in order to give a direct increase in pump discharge. Various means of regulating the speed of the pump drive units have been employed. A recent development has been the use of variable pitch propeller-type pumps for large installations. In the variable speed pumping field use has been made of variable speed electric motors, electric motors with vari-drive units, and gas engine units. These have given satisfactory service in small installations, but require considerable maintenance and adjustment of the speed regulating controls to keep them in acceptable working order. From our experience it is not possible to have fully reliable automatic speed control units on variable speed pumping. Because of the difficulty in control of the variable speed pumping, most of the pumping station installations have used multiple pumps, which give step operation approximating the flow curve.

Number of Pumps

One of the important determinations is the number of pump units to be provided. Normally, we have found that four pumps will handle the range of flows that might be encountered between minimum and maximum. In a pumping station for normal domestic sewage all four units can be of the same size. This permits maximum flexibility, in that any one unit may be in service or held for stand-by. However, in stations where large storm or industrial flows might occur it is sometimes necessary to have pumps of different capacity, with a definite schedule at which the various pumps will go into operation. This, however, has the disadvantage that the small

pumps run almost continuously and the large pumps are used during short periods of the day or, at times, for short seasons during the year. An example of pump selection is shown in Figures 1 and 2. Figure 1, a plot of head *vs.* discharge used in selecting a specific 10-m.g.d. pump, shows the effects of variation of head on the pump discharge. A similar plot was made to select a specific 20-m.g.d. pump. Figure 2 is a pumping program for two 10-m.g.d. and two 20-m.g.d. pumps at 30-ft. total dynamic head. In this example, the pumps selected are capable of delivering 70 m.g.d. under low head conditions, instead of the nominal 60 m.g.d.

As suggested before, a pump station serving a main trunk sewer or at the headworks of a sewage treatment plant should be designed for the anticipated ultimate capacity of the sewer system. This would mean that except for unforeseen developments there would be no structural change in these units after they were once put into service. However, the financing available would be a determining factor as to how many of the pump units would be installed in the original construction. If the flow is considerably below that expected, it would be quite proper to defer the installation of a pump with proper provision made for its installation at some future time. It is also possible, as has been done in some designs with which the author has had experience, to select pumps with case size such that a new impeller can be installed at a later date, thereby increasing the discharge. This would also involve a new motor drive unit, but it eliminates any future piping changes during a change-over period.

An item also concerned in the selec-

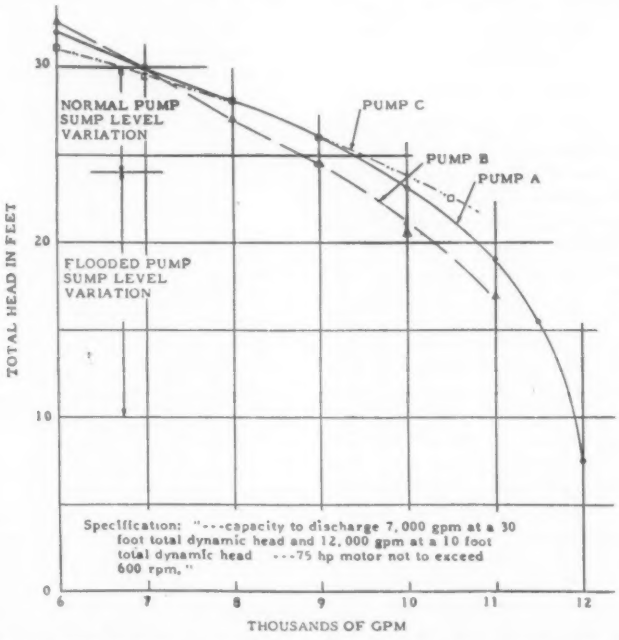


FIGURE 1.—Head-discharge curves for selection of 10-m.g.d. pumps used in Figure 2.

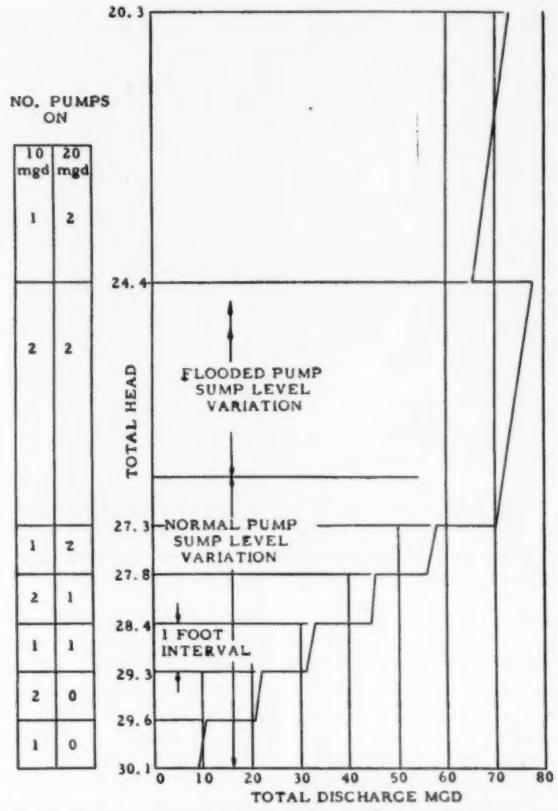


FIGURE 2.—Pumping program for 30-ft. lift station containing two 10-m.g.d. and two 20-m.g.d. pumps.

tion of a pumping unit is the selection of the pump drive. Normally, modern sewage pumping units are driven by electric motors, although it is possible to use Diesel engines, sewage gas engines, or, as in some of the large eastern plants, steam-turbine drives. The writer feels that electric motor drives are the best all-around units to install. They can be controlled and adapted to installations in the pumping structure more easily than a Diesel engine or a gas engine drive unit. With the advent of the dual-fuel, Diesel-gas engines, it appears that these units would be the best method of utilizing sewage digestion gas for the generation of power, with this power applied to electric motors, which are easily controlled with standard electrical equipment. However, it would be well to bear in mind that in the installation of electric generating units to provide power for sewage pumps they must be properly sized to take care of the maximum load that may come on them from starting conditions.

Pump Arrangement

Selection of the pump arrangement is a matter of personal preference with the designer. Most of the pumps of

FIGURE 3.—Multiple horizontal pump installation. Note ample work space, access stairs with handrail (in background), and ventilation ducts (upper left).

standard manufacture can be obtained in many different arrangements. It is possible to install them as horizontal units, vertical with motor directly above, or vertical with extended shaft and drive unit on a floor above. The horizontal pump arrangement is believed to have a little advantage in that it is easier to align on a unit base (see Figure 3). It presents a little more workable installation as far as maintenance operations are concerned. On most horizontal pump installations a split case unit will allow ready disassembly for cleaning or maintenance of bearings and impellers. The vertical pumps, either close-coupled or with the extended shaft, have an advantage in that they require less sump room for the same working clearances and are very definitely advantageous where a deep sump must be constructed in difficult ground. The main reason for using a vertical pump with extended shaft is to place the electric motor drive units above any possibility of flooding. In some installations, the extended shaft has presented problems in proper alignment. In several installations the writer's organization has used enclosed shafts comparable to the shafting used on water well turbine pumps. These have given very satisfactory service when properly installed.

Additional Design Hints

The location of the pumps in the flow layout, the determination of the capacity and head to be met, and the selection of the pumping units both in capacity and number are the basic considerations required for a pumping station. However, satisfactory operation of a sewage pumping station depends to a large degree on the design features incorporated in the final installation beyond proper determination of the basic design items noted above. Some of the items noted hereafter should prove of interest and value to designers working on future sewage pumping stations and might be described as design hints worth passing along.

Small Stations

A universal problem is to design small sewage pumping stations at as reasonable a cost as possible. We have designed several in the immediate postwar period that were thought to be simple and economical to construct. However, the bid prices for construction of what were thought to be simple pumping units were disappointing. In one small sewage collecting system requiring two pumping stations and where available funds were very limited, it was finally decided to modify the original pump station entrance manhole to provide an emergency wet-pit pump installation. These have operated quite successfully.

In other recent installations, small local area pump lifts have been designed using a wet-pit submerged vertical pump. These consist essentially of an oversized manhole with a slab containing a manhole opening, in which is suspended a vertical non-clog sewage pump with the motor resting on top of the manhole frame. This arrangement includes a small "doghouse" type motor cover, which can be easily removed except for a fixed side, on which the electrical controls are mounted (see Figure 4). An easily connected, aboveground pump discharge and easily disconnected electric motor power service have been provided so that in case of a pump stoppage the discharge line and power service are disconnected and the pump lifted out by means of a garage tow truck hoist or a small A-frame. Recent installations of this type have used the new Fairbanks-Morse bladeless impeller and have given excellent results.

Another design that has been used in an attempt to reduce costs has two adjacent sections of precast concrete pipe units placed vertically with connecting piping cut between one unit acting as a wet well and the other as a dry-pit pump structure. This design eliminates form costs, which seem to be running far beyond prewar price ranges. This type of construction permits a complete underground pumping unit that can be located beside the road or parkway (see Figure 5).

Neither of these designs can be recommended as ideal from a maintenance standpoint, but they have provided sewage pumping facilities for a very low cost. In small pumping stations where funds are available several small wet and dry sump type units using the Flush-Kleen system of the Chicago Pump Company have been installed. These have given excellent results with a minimum of maintenance problems. In this type of dual pump installation the wet pit is to take care of the liquid only, as the solids are strained out by

FIGURE 4.—Small capacity pump station with wet-pit pump installation and small removable house.

a special strainer as the sewage flows into the sump through one pump and are flushed back by the pump when it operates on its alternating cycle without any likelihood of causing pump stoppage.

Debris Screens

In larger pumping stations, considerable thought should be given to the arrangement, particularly with regard to ease of maintenance and operation. With the larger sewers coming into the plant there is the possibility of coarse solids entering the sump that would cause pump stoppage. Primary pump protection can most easily be provided by hand cleaned bar racks with 3-in. to 4-in. spacing between the bars. Secondary pump protection can be provided by fine bar screens, either hand or mechanically cleaned, or by comminutors or similar screenings grinders. The comminutors give the best performance with the least daily operating care. On large installations a mechanically cleaned bar screen with separate screenings grinder gives a more economical installation. All of these screens or grinders need regular operating care. They should be easily accessible and have adequate work platforms around them.

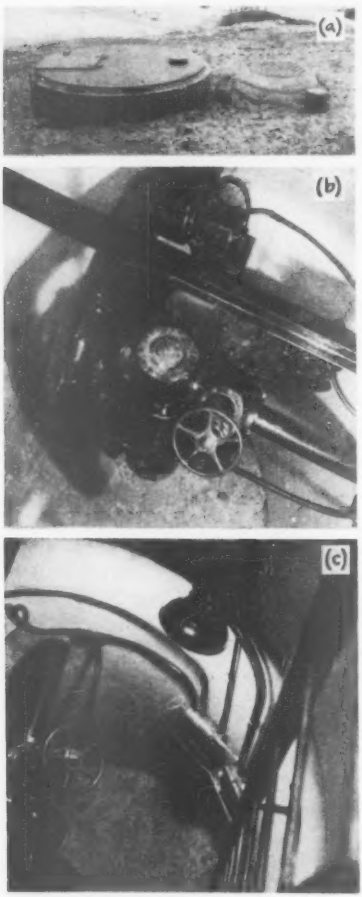


FIGURE 5.—Small capacity pump station for underground installation using precast concrete pipe units, showing: (a) Access covers. (b) Pump and ventilator arrangement. (c) Electrical controls.

FIGURE 6.—Concrete ogee on inlet to sump to prevent splash, odor liberation, and excessive turbulence.

Inlet Channels and Sumps

Inlet channels into the sewage sump should be checked hydraulically to

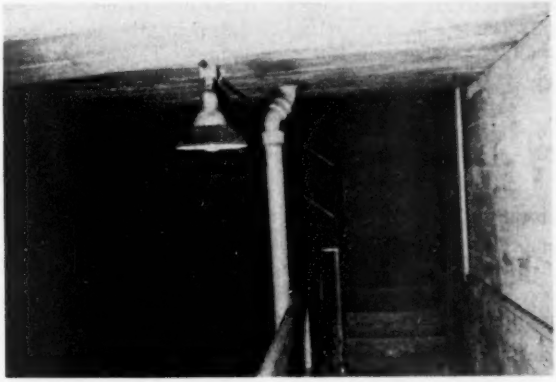


FIGURE 7.—Stairs with handrail replace hazardous manhole-and-ladder access to wet pit.

make sure that they will flow into the sump with a minimum of liquid disturbance. If there is an appreciable drop during low sump level an ogee section should be installed to bring the water from the pipe invert down to the low level inside the sump (see Figure 6). A waterfall generates water spray and may liberate objectionable odors.

If the pumping station cannot be by-passed during periods when necessary for sump cleanout or pump maintenance it would be well to provide a two-unit wet sump. With this arrangement either could be used during short periods while the other side is out of service. If an emergency by-pass is available this provision can be eliminated.

It is felt that the wet sump side of a pumping station is as much an operating unit as a sedimentation tank in a treatment plant. As such we have provided easy access to this part of the structure. The old type sewage sumps provided manhole steps into a deep dark hole. These were extremely hazardous to the operator and were very seldom entered except under direst emergencies. The design of many West Coast plants has provided for easy stair access to the wet sump (see Figure 7). Also, landings and platforms a short distance above the normal sump operating level have been provided so that the operator can wash down the sump sides and knock down accumulated scum and floating materials (Figure 8). In addition to this, we have provided a method of skimming the wet sump. This has involved the installation of a bell mouth, facing upward, connected into the suction side of one pump. The operation of this skimming device is con-

FIGURE 8.—Railed operating platform in wet pit facilitates washdown and sump skimming. Hose for washdown is conveniently placed on wall to left of motor control.

trolled by double-valving or by a three-way plug valve on the pump suction to provide the alternate suction inlets. The single pump with the sump skimmer arrangement on it is manually controlled during the skimming operation by an alternate switch adjacent to the walkway in the wet pit. With a little experience an operator can gage the time of day when he can get the most effective skimming by using the manually controlled pump, together with other necessary sewage pumps, to skim off the surface of the sump as required.

Ventilation

One of the most important items in connection with modern sewage pumping station design is the provision of adequate ventilation. Ventilation is required in both the wet pit and the dry pit inside of the station.

Adequate ventilation in the wet sump can keep the air clean and fresh. It removes all objectionable odors as they originate and also prevents accumulation of any dangerous concentration of gasoline vapors. Proper ventilation makes a potentially dangerous area safe. Experience has shown that, generally, a 3-min. displacement air change is sufficient to keep this section properly ventilated. However, it is necessary to give proper consideration to the distribution and mixing of the air, as well as its straight removal. In one installation the mistake was made of drawing the air in through the inlet channel. This area was supersaturated with water vapor, which caused excessive condensation in portions of the sump away from the ventilation outlet pipe. Ventilation of the dry-pit section where the pumps are located is necessary to keep a fresh air condition. It also aids in preventing any condensation of moisture around the suction or discharging piping.

Electrical Controls

Brief mention should be made of the controls included with normal electric pumping units. The writer does not favor providing elaborate recording or indicating instruments that will not be used except for a research project. Nevertheless, a very necessary and useable item for all pumping stations is a time clock to show the time which each pump operates. This is invaluable in a program control where the different pumps can be put in the first operating position and it is desired to balance the operating time of the various units.

Several installations of floatless water level controls have been tried. They become coated with grease layers and are difficult to maintain and service. On the basis of this experience it is concluded that a standard float with multiple contacts still seems to be the best all-around unit.

DISCUSSION

By Grant M. Olewiler

Superintendent, Sanitary Drainage, Lower Merion Township, Ardmore, Pa.

Mr. Kennedy's paper seemingly contemplates small lift stations designed to avoid excessive depths of sewers in flat country; lifting of sewage from an interceptor to the operating level of a treatment plant; or consolidation of several drainage areas by pumping their sewage to a central area, evidently at a low head. In Lower Merion Township, Pa., there are a number of watersheds contiguous to a stream where possible pollution is intolerable because of the proximity of Philadelphia's drinking-water intakes. However, by pumping over a divide it is possible to use an adjacent watershed for disposal at a point miles below the water intakes

and thus eliminate the excessive expense of long and worthless transmission lines. In this case the heads greatly exceed those contemplated by Mr. Kennedy: the minimum is 65 ft.; the maximum, more than 250 ft.

The reference to the small amount of foreign matter contained in the water of the sewage is appreciated, but it should be pointed out that to try to prove this to men working on the sewers or in the pumping stations is very difficult. Their reaction is: "So much trouble and work could not possibly come from so little material."

The author makes the point that in all cases the pumping station should be designed to take care of the ultimate maximum flows of the tributary pipe system. This is open to disagreement unless the entire watershed is to be developed within a very short space of time. One of the four stations in Lower Merion Township has been in operation more than 45 years and still carries less than one-half the probable ultimate load. Under these conditions the ability to install larger pumps, either in the present building or in an extension wing, is greatly appreciated. This will not apply to the pressure main, which must be of the maximum size because a nominal increase in the pipe size will cost very little during the initial installation as compared with the construction of a new line years later.

Much has been said and written in advertising about the efficiencies of the pumping units, but in our experience mirror finishing of an impeller to meet an installation efficiency guaranty is of little value after the pump has operated for six months. The abrasive character of the material handled soon destroys the finish. Because the pump has been accepted and the contractor paid, no one is willing to again stir up such a a fine point as the efficiency, especially as there are so many variables involved and even the motor manufacturer will refuse to guarantee the motor efficiency under field conditions.

Use of variable speed pumps to keep the flows to treatment plant units in continuous proportion to the incoming sewage volumes does not seem to be a substitute for pumps of different capacities. This is because of the very poor efficiencies created when the impeller speeds drop below the top of the design curve for the pump. This conclusion, however, is based on the high heads encountered in the Lower Merion Township installations and may not apply to the small heads considered by the author.

Because local pumping costs are influenced materially by the maximum kilowatt demand measured for each 30-min. interval for one month, it has been possible to effect power savings in the smaller stations by installing electrical control clocks, which limit the pumping to a predetermined portion of the half hour. Although exceptionally stormy weather at times may necessitate throwing the clocks out of service, this does not usually happen during more than two or three months a year.

Although local installations include both horizontal and vertical pumps, agreement is found with the author in favoring the horizontal, because of the ease of doing maintenance work. The vertical pumps created quite a problem in maintaining bearings, although this has been overcome by the use of universal couplings on the shafting.

In two of the original stations (erected in 1904) the pumps were located above the level of the collecting wells and were hand primed by the return of sewage from the pressure main to exhaust gas from the pump housing. Installation of vacuum pumps and air release valves has permitted automatic float control of this equipment. Except for small clearance in the air release valve, which requires periodic cleaning, and the necessity of replacing cotter pins in the linkage, the vacuum priming has been successful and is recommended for places

where ordinary installations are not practical. In installations of this type it is extremely important that the suction line be graded to eliminate gas deposits along the top of the pipe.

Because proper lubrication is so essential to successful maintenance, especially when working against high heads, horizontal pumps should be provided with some device to prevent sewage which leaks past packing from following the shaft and entering the oil reservoirs in the pedestal bearings. High-pressure lubrication should also be provided for packing, while the pump is in operation, because no extra grease is needed while the shaft is at rest. Spring tension grease cups protected by check valves had to be discarded in the installation mentioned because of the high heads, but are offered as a suggestion for use with lower heads.

Although Mr. Kennedy suggests a disadvantage in the use of pumps of different sizes because the smaller sizes do almost all the work, this has proven to be an advantage in the Lower Merion Township installations. Pumps must be rebuilt when they wear, and it has been found far cheaper to replace the operating parts of the smaller pumps. Again, the electrical demand charge will reduce the monthly bill if it is possible, even for a portion of the year, to operate only the smaller pumps.

Although not strictly a matter of pumping station design, it is recommended most strongly that in the installation of any pumps the engineer demand and withhold payment until dimensional plans of the equipment furnished are given to the municipality. Experience with procurement of replacement parts has established this as a primary necessity.

Also strongly urged is the installation of sufficient valves to isolate each pumping unit during repairs or maintenance work.

It is true that the examples given of low-cost pump housing and installation of pumps in wet wells are cheap in installation cost. But what about the operation and maintenance costs? In the writer's experience initial costs have been far easier to obtain than replacement expense. Surely the cost of decent pump housing, good for the life of a sewer system, is a proper expense, which must be borne by the properties benefited. It should not be reduced to an unjustifiable minimum so that a group of developers may receive a greater return on their investment at the expense of those to whom they sell the houses, especially as these new owners must as citizens bear the expense of operation, maintenance, and replacement.

There would certainly be objection to working on the electrical controls of the pump station with the removable house during stormy weather. The question also arises as to what happens when the overload kicks out with only one pumping unit to depend on and no operator is around to start action to replace faulty equipment.

Although the local installations handle only so-called sanitary sewage, a relatively large amount of street washings, cinders from icy roads in the winter, ground screenings from asphalt coating of roads in summer, and just plain grit from other periods, washes through the openings between manhole frames and covers, and enters the sewer. Soil washes through low fresh-air inlets on main house traps, and dirt and road stones gain access to the lines while connections are being made and storms overtake contractors before they have completed their work. Grit removal prior to pumping, therefore, must be a primary consideration if the pumps are to be spared the unnecessary wear to all their parts which this abrasive material is certain to produce.

Although all of the Lower Merion Township stations were provided with fine bar screens, hand raked, consider-

able quantities of stringy rags would pass the screen either because of the velocity of the water through the openings or because the rakes would dislodge the underwater material. The trouble this by-passed material could create was vividly shown in one station, which has 4-in. two-stage pumps, when installation of a comminutor reduced almost daily packing of the pumps to once in three weeks, eliminated removal of rags from around pump shafts and impeller several times a day, and reduced the electrical demand more than 20 per cent.

Although the comments on the wet sumps are very appropriate, our exceptionally small volume of industrial waste, because of the strictly residential character, plus outside location with good ventilation limits odors and provides natural light over ladder steps, which are located under large double doors.

The author's comments on easy stair access are equally adaptable to the means of access to dry wells housing pumps. Although steep spiral stairways are a trial whenever materials have to be carried down them, the writer recently was in a new pumping station where the steel staircase was so steep it could only be descended backwards and an attempt to carry anything would result in a fall.

Ample means of lifting and moving equipment of all types should be provided. Although overhead tramways are desirable, moveable bridge truss hoists, such as sold to automobile repair shops, have been found to be very handy.

Another primary requisite is sufficient tools to properly take apart all equipment. It should be remembered that it takes two wrenches to properly free a bolted section. Tool boards, with hangers for each tool and a requirement that tools must be replaced, have resulted in a marked reduction in the number of tools lost, as well as a great saving of time in hunting the proper tools. Such a board should be painted a light color, with darker silhouettes of the various tools in their proper places.

Along with ventilation of the pump rooms, proper heating and ceiling insulation also should be stressed. Since insulating and providing a suction exhaust fan in two stations, the interiors are kept very comfortable in the hottest weather with a maximum of two screened windows being opened, as compared with the former practice of opening a large number of unscreened windows and several doors without appreciable benefit. Elimination of the large quantity of winged insects and dirt, which formerly accumulated in motor windings, causing them to become hot, demonstrated the value to the equipment as well as the relief of nuisances to the men.

Electric accumulating recorders, which indicate the length of time each pump operated are also used, but it would be desirable for each station to have a daily record of the volume pumped and a non-recording pressure gage on the discharge line from each pump. It must be remembered that the Town Fathers like to hear reports on what has been done as a justification of expenditures.

Because it was extremely difficult to maintain cables or chains for floats on water level control switches, floats on galvanized pipe lever arms were adopted. These have proven very satisfactory.

Although the author does not mention it, to be complete the design should include a strong recommendation of the personnel necessary to properly operate and maintain any pumping station. With modern electrical warning devices and protective equipment the force may be reduced somewhat over that necessary years ago, but it must be remembered that every such device is another item to be maintained if it is to be depended upon in an emergency. This requires men on the job who understand thoroughly the use

and care of each piece of equipment. A policeman assigned to look into a station several times a day to see if he can hear the pumps running or to see if the fire is still burning, would hardly fill this requirement.

Even if the community is exceptionally small, some effort should be made to have the equipment supervised at regular intervals to detect parts which are not functioning properly. An experienced maintenance mechanic or two, working with the regular operator, could then replace worn or broken parts. These men can also be used as relief men for regular operators if the force is too small to provide a regular relief man.

MAINTENANCE AND OPERATING PRIORITIES

Regulation 4 of the National Production Authority permits all business establishments and other non-business institutions—large and small—to use an extendible DO–97 rating to obtain needed maintenance, repair, and operating supplies and materials (MRO). It should be noted particularly that, with the single-band priorities system now in force, all orders with a priority rating, regardless of the program identification number, receive equal treatment.

Another noteworthy feature of the regulation is that use of the DO–97 rating is not mandatory, but purely permissive, and that no special authorization is required for its use. However, if use is made of the rating, then total acquisition of MRO, both rated and unrated, becomes subject to the quarterly limitations set up by Regulation 4. These quarterly quotas are figured on the basis of MRO purchases in 1950.

To use the rating, the purchaser must show on his order or supporting papers the statement: "DO–97, Certified under NPA Regulation 4," with proper signature and identification of the responsible individual. Purchase of MRO supplies up to $1,000 per quarter requires only a record of the transactions; above $1,000 per quarter requires recording of the expense against the allowable MRO quota. The rating may be used on non-rated orders already placed for MRO supplies.

Provision is made for necessary quota adjustments by filing a request with NPA setting forth the reasons for the required increase. Similarly, provisions are made for seasonal and new enterprises to establish quotas.

EXPERIENCE WITH UP-SEWER CLOROBEN TREATMENT IN SOUTHERN CALIFORNIA

By Richard Pomeroy

Partner, Pomeroy & Westcott, Consulting Engineers, Pasadena, Calif.

Experiments on the use of Cloroben * for sulfide control in sewers have been going on in Southern California for several years. An attempt has been made in this paper to collect all locally available quantitative information of a type which will permit conclusions as to effectiveness of Cloroben for elimination of sulfide generation. This discussion is directed only toward the question of sulfide control in sewers, although Cloroben has been advocated on occasion for several functions besides sulfide control, such as bacterial reduction, odor masking, etc.

Laboratory Experiments

One approach to the evaluation of a chemical procedure for sulfide control is by laboratory experiments. Sulfide generation in bottles is quite different from generation in sewers, but properly planned laboratory tests may yield valuable information. The results of two sets of tests have already been reported by Pomeroy and Bowlus (1). It was found that dosages of 5 p.p.m. or less had no discernible effect on sulfide production in bottles. A dosage of 64 p.p.m. served to cut the rate of sulfide generation in half. By comparison, equal results were obtained by 6.5 p.p.m. of a chlorinated propane-propene mixture, and by about 3 p.p.m. of chlorinated phenols.

Laboratory tests by Beardsley (2) showed that the sulfide-producing activity of slimes was not significantly diminished by exposure for four days to Cloroben at a concentration of 30 p.p.m. However, a cleaned concrete surface in a sewer, when disinfected with Cloroben, remained free of sulfide-producing slime through an observation period of more than a year.

Eliassen, Heller, and Kisch (3) have presented data to show that fractional parts of Cloroben can retard sulfide production from organic matter, but that concentrations up to 50 p.p.m. were ineffective against the sulfate-reducing organism *Sporovibrio desulfuricans*. The theoretical possibility was presented that in sewers Cloroben might delay the fall of oxidation potential and thus might postpone reduction of sulfate.

Field Observations

The field data which have been assembled here for appraisal of the effect of Cloroben on sulfide generation in sewers are presented under the headings of seven cases.

Los Angeles County Sanitation Districts

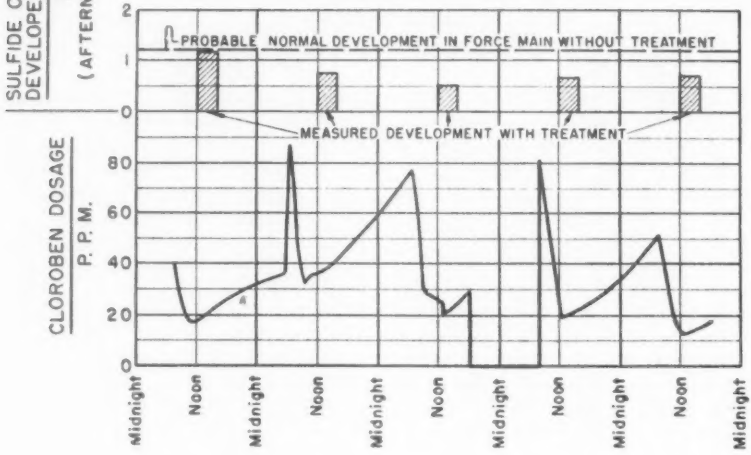
Cloroben was tried by the Los Angeles County Sanitation Districts in the San Gabriel system in 1942 and 1943. Application was at the wet well of a pump station, which delivered an average of 0.5 m.g.d. of sewage into a 7,300-ft. force main. The sewage received at the pump station was fresh, with total sulfide concentrations never more than a few tenths of a part per million and with dissolved sulfides generally zero in the summer and in-

* "Cloroben" is the trade name for an emulsified mixture of chlorinated benzenes, as produced by the Cloroben Corporation. "Benoclor," also referred to in this article, is another product of the same company and is likewise essentially chlorinated benzenes.

FIGURE 1

EFFECT OF CLOROBEN ON DEVELOPMENT OF SULFIDES IN SEWAGE FLOWING THRU SAN GABRIEL FORCE MAIN

January 25-29, 1943



variably zero in the winter during the period of the Cloroben tests. Considerable build-up of sulfides occurred in the force main; it was in an attempt to eliminate this that Cloroben was tried.

Preliminary tests in December, 1942, with low dosages of Cloroben showed no clear evidence of sulfide reduction, but the results were uncertain because of difficulties with the feeding arrangements. In January, 1943, a fairly satisfactory run was obtained with high dosages, as shown in Figure 1. Cloroben was fed at a roughly uniform rate (except for a 14-hr. interruption), but considerable fluctuation of concentration, as shown in the graph, resulted from the variations of sewage flow. Normal sulfide increase in the force main, shown as 1.2 p.p.m. in this figure, is not accurately known, because occasional winter storms cause erratic results; it could be as low as 0.75 p.p.m. or as high as 1.50 p.p.m. Sulfide concentrations at the end of the force main were determined on each test day by 10 or more determinations. On the basis of the assumed normal build-up of 1.2 p.p.m., it appears that an average of 35 p.p.m. of Cloroben reduced sulfide generation by 37 per cent. The magnitude of this reduction is uncertain, but it was evident that Cloroben failed to accomplish the aim of stopping sulfide generation.

It was subsequently pointed out by representatives of the Cloroben Corporation that better results might have been obtained if the chemical had been applied upstream at the end of a lateral to get a greater contact time. To put Cloroben into the end of each lateral, so as to obtain contact time with all of the sewage, would have been impractical, so the Districts decided against any further attempts to use Cloroben in this situation. Zinc sulfate was found to be completely effective and was used until this station was abandoned in 1944.

City of Los Angeles

It is well-known that the City of Los Angeles has done much work with Cloroben (4). The primary purpose of this work was bacterial reduction of beach waters. On the basis of certain laboratory tests its use was indicated, and the city was faced with the desperate necessity of doing whatever showed reasonable promise of improving conditions. With a problem so serious, the city did not feel warranted in making extensive off-and-on experiments, such as have been possible in other places. Consequently, the establishment of comprehensive data on the effect of the chemical on sulfides has been delayed.

The opinion has become current that sulfide concentrations in the Los Angeles north outfall generally ran in the neighborhood of 10 p.p.m. before using Cloroben. Results as high as 10 p.p.m. may have been reported some years ago, but since that time sulfide testing methods, including the significance of the term "hydrogen sulfide" have changed; sewer cleaning and maintenance have been improved, flows have increased, and by opening of manholes at locations in the sewer where oxygen concentrations in the atmosphere were found to be a little over half normal, the concentration has been brought up to near normal for the entire length. Unfortunately, observation and sampling were necessarily curtailed during the war years and there is a gap, during which time sufficient information was not available to observe the trend of sulfide concentrations.

Upon resumption of regular scheduled sampling it was noted that sulfide concentrations at Hyperion had dropped to the order of 1 to 1.5 p.p.m. The incidence of the lowered concentrations cannot now be correlated with any particular change in technique, operation, or any other factor.

The City no longer uses Cloroben for sulfide control.

City of Long Beach

The City of Long Beach started an energetic program of sulfide control in 1946. Many sewer lines were cleaned and Cloroben applications were started in three locations. Unusually complete data are now available for the evaluation of Cloroben in this system.

The records are particularly significant in the North Long Beach system. Cloroben was applied, under the supervision of the manufacturer's representatives, at two points near the upper end of trunk sewers, in sufficient amount to yield a concentration of 1 p.p.m. in the total flow. The sewage flows to a pump station, where it is pumped into a 4,200-ft. force main. The city followed a routine test procedure, in which one test was made each day at the end of the force main. Over the period of these studies, the testing time at this point was between 12 noon and 1:30 P.M., which is on the sulfide "plateau" lasting most of the afternoon in this line.

Figure 2 presents these results over a 23-month period, including three periods of Cloroben dosage and four periods without Cloroben. In this plot, the individual daily results have been averaged by groups, generally of five days, to smooth out the sharp day-to-day variations. The points shown on the plot are these averages and represent total sulfides; dissolved sulfides average just 1 p.p.m. lower. With this complete record now available it appears that Cloroben had no significant effect, an observation contrary to conclusions reached after preliminary tests before these on-and-off experiments.

In respect to the results of these on-and-off experiments, two points have been raised as to the soundness of the conclusion. The first is that these sulfide concentrations are lower than in previous years. In 1941, during a period of no treatment in October, total sulfide concentrations rose to between 6 and 7 p.p.m., as compared to concen-

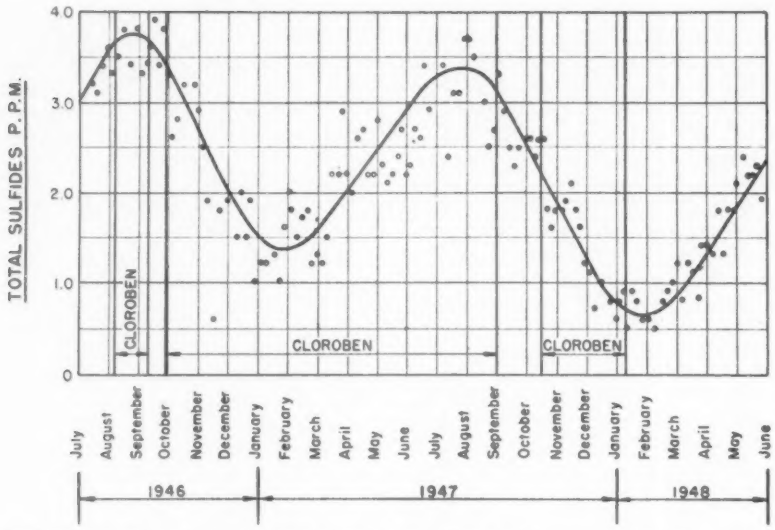


FIGURE 2.—Cloroben experiments in North Long Beach force main; dosage 1 p.p.m. during intervals noted.

trations of 2 to 4 p.p.m. at the same season in 1946 and 1947.

There are two factors which account for the change since 1940. One is that the City of Long Beach did an extensive cleaning job in the sewers in this area, which would certainly lead to a reduction in sulfide generation. The other is the increase in flow, which is especially important in force mains, where the build-up of sulfide concentration is inversely proportional to the flow. The 23-month period recorded in Figure 2 displays a continuing downward trend in sulfide concentrations, which can be explained by the two factors mentioned.

The second point raised concerns the ability of Cloroben to have a persisting effect. In order to maintain that Cloroben was a factor in this reduction since 1940, it would be necessary to assume that its effects persisted undiminished for extended periods of time after the shutting off of treatment.

It is known that certain sterilizing chemicals do have effects which persist after cessation of treatment. There is much information on this point, for observations have been made of this effect in the use of chlorine, lime, caustic soda, sulfuric acid, and shock treatments of Cloroben and Benoclor. In summer, the effect seldom persists for more than seven days. In winter, it may take a longer time for the sewer to return to normal, but there is no clear evidence that these effects ever last longer than two weeks.

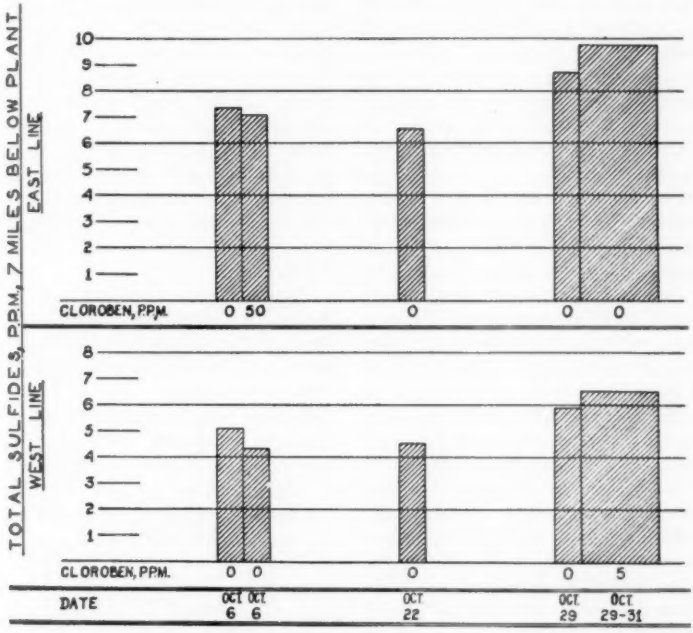
Cloroben was also tried for control of sulfides in force mains in the Los Alamitos and Belmont Shore districts in Long Beach. Without going into detail, it may be said that treatment of the pump station wet wells with high dosages of Benoclor stopped sulfide generation for a few days, but a continuous repetition of this treatment was uneconomical. Cleaning of the force mains helps, but no practical combination of cleaning and Cloroben treatment has been found which accomplishes satisfactory economic control. Other procedures, such as chlori-

nation, compressed air, or metallic salts, are indicated as more economical in the solution of this problem.

City of San Buenaventura

The City of San Buenaventura ("Ventura") consists principally of a long narrow developed area paralleling the beach. A trunk sewer takes the sewage to a treatment plant at the northwest end of the city. Sulfide production is small, with an average of 0.26 p.p.m. of dissolved sulfide in the sewage when no treatment was applied. However, the location of the treatment plant is such that it is desirable to hold dissolved sulfides to zero at all times.

In a trial run, Cloroben was added at the upper end of the trunk sewer during August, September, and October, 1947. The dosage was sufficient to give a concentration of 1 p.p.m. at the lower end of the line. Sulfide tests were made only on a few days scattered over the season, including only two days during the period of treatment, showing an average dissolved sulfide concentration of 0.20 p.p.m. for



SUMMARY OF RESULTS

DATE	CLOROBEN DOSAGE, P.P.M.		AVERAGE SULFIDES, P.P.M.		RATIO	NUMBER OF TESTS IN EACH LINE
	WEST LINE	EAST LINE	WEST LINE	EAST LINE	WEST LINE : EAST LINE	
OCT. 6,22,29	0	0	5.02	7.34	0.68	25
OCT. 6	0	50	4.3	7.1	0.61	8
OCT. 29-31	5	0	6.55	9.74	0.67	24

FIGURE 3.—Sulfide generation in Santa Fe Springs Waste Water Disposal Co. effluent lines.

seven tests. From the scant data it is not possible to say whether Cloroben had any effect, but because sulfides were not eliminated, the City discontinued the treatment.

Santa Fe Springs Waste Water Disposal Co.

The Santa Fe Springs Waste Water Disposal Co. operates a plant treating 3.5 m.g.d. of oil field waste water by flocculation, sedimentation, and filtration. The effluent goes through two parallel pipelines to the ocean. Sulfides are often present to the extent of a few tenths of a part per million in the water leaving the plant. However, there is considerable aeration at the entrance to the pipelines, and at a point a few hundred feet downstream total sulfides were consistently 0.1 p.p.m. or less.

The effluent lines are tightly closed, so that there is little or no ventilation. Considerable sulfide build-up occurs as a result. The two lines handle the same water, but different flow conditions lead to differences in sulfide generation, with concentrations in line No. 1 generally about two-thirds as great as in line No. 2.

On Oct. 6, 1947, Cloroben was added to line No. 2 for a few hours at a concentration of 50 p.p.m. Tests were made in both lines at a point 7 mi. downstream before the Cloroben arrived and for 2 hr. while the Cloroben was passing. Later in the month another test was run, this time by adding Cloroben for three days to line No. 1 at a dosage of 5 p.p.m.

All of the results are represented in Figure 3. The statistical summary at the bottom of Figure 3 shows that the two lines behaved similarly in fluctuations of sulfide concentration, regardless of the presence or absence of Cloroben. The ratio of average sulfide concentrations in the two lines does not change materially in a direction that would indicate any benefit from Cloroben, and it therefore was concluded that Cloroben had no significant effect in these experiments.

Buena Park

In Orange County, Cloroben was first tried in 1942. No conclusive data are available, but the results did not appear promising and the treatment was discontinued. In 1947 tests were made at Buena Park, Orange, and Santa Ana.

At Buena Park two collecting lines take the flow, totaling 200,000 g.p.d., to a pump station, which delivers it into a 2-mi. force main. Cloroben was added at two points near the upper ends of laterals on one of these collecting lines, and at one point on the other. Dosage was 3 p.p.m. in the total flow. The treatment was applied from April 2 to April 11, inclusive. Tests before, during, and after Cloroben addition were taken in each of the two main lines entering the pump station, with average results as shown in Table I.

The tests on April 22 and 25 are distinctly higher than during the first week of the month, but the increase is about what would be expected for the seasonal trend.

Within the limits of erratic variation, the results do not show that sulfide conditions were appreciably im-

TABLE I.—Cloroben Experiment at Buena Park, Calif.

Date	Cloroben Dosage (p.p.m.)	North Line		South Line	
		Number of Tests	Total Sulfides[1] (p.p.m.)	Number of Tests	Total Sulfides[1] (p.p.m.)
April 1	0	7	2.26	7	1.86
April 2	3	5	2.44	5	1.84
April 3	3	5	2.38	5	1.48
April 4	3	5	2.16	4	1.58
April 7	3	3	2.17	3	2.00
April 11	3[2]	—	—	—	—
April 22	0	3	2.80	3	2.27
April 25	0	3	2.83	3	2.07

[1] Average.
[2] Cloroben treatment discontinued.

proved by Cloroben treatment, but examination of the Buena Park system showed that the sulfides probably came largely from short laterals tributary to the two main collecting lines. Under these conditions complete elimination of sulfides at the end of the line could scarcely be expected from addition of a toxic chemical to the main stream, unless biological activity is reduced so far that substantial oxygen concentrations build up in the stream. As addition of Cloroben to each lateral was impractical, it was concluded that Cloroben was not of practical use in this situation.

In the Buena Park force main, when no treatment was applied, sulfides built up to concentrations of 10 to 12 p.p.m. This was unaffected by the presence of Cloroben at a concentration of 3 p.p.m. Compressed air normally accomplishes complete control in the force main.

City of Orange

The second set of tests in Orange County were made in the main sewer from the City of Orange. This line runs for a stretch of 2 mi. from the city limits to the Verano-Euclid line of the Joint Outfall sewer. The sewage is generally free from dissolved sulfides at the city limit, but when no controls are applied, sulfide build-up occurs before the sewage reaches the Joint Outfall line. Concentrations are erratic, due to operations of a cannery at Orange. It is not possible to state just what is normal for this line, but the available records show that in summer dissolved sulfide concentrations of 1 to 3 p.p.m. can be expected on most days when there is no treatment.

Prior to the experiments with Cloroben, sulfides had been kept under control by shock treatments with lime. These treatments, which consist in adding 800 lb. of lime over a period of a half hour, have been completely effective in preventing the reappearance of any dissolved sulfides at the end of the line for a week, and sometimes longer.

On August 4, 1947, sulfides had reappeared after a lime treatment about two weeks earlier. Cloroben was fed for four days at dosages varying from 1.25 to 5 p.p.m. Dissolved sulfide concentrations averaged 1.1 p.p.m. (14 tests). Due to feeding difficulties, the Cloroben dosage averaged only 0.5 p.p.m. for the next four days. Then the sewer was dosed at 10 p.p.m. for one day, followed by 2 p.p.m. for five days. In this 6-day period, also, dissolved sulfides averaged 1.1 p.p.m. (14 tests). In the absence of accurate basic data on sulfide concentrations without treatment, it is not possible to determine whether there was any effect on sulfide generation, but at the dosages used, Cloroben did not produce real control of sulfide formation.

Santa Ana

In May, 1947, plans were made for a series of tests in Santa Ana under the guidance of representatives of the suppliers of Cloroben. The sewers selected for testing were a series of badly fouled laterals on Sycamore, Broadway, Birch, Van Ness, and Ross, tributary to the Delhi trunk. Each of these laterals is about 0.25 mi. long, and picks up sewage from 50 to 150 homes. Tests were made on 8 days from May 1 to May 9 at the points of junction with the Delhi trunk. Because of the foul condition of the lines, the Cloroben representatives advised trying certain initial treatments of flushing or shock dosages of chemicals, after which it was intended that regular Cloroben dosages would be applied. Table II shows initial sulfide concentrations, treatments applied, and results on subsequent days. The failure of the shock treatments with Cloroben and Benoclor to cause more than a partial reduction of sulfide generation was discouraging, and the Cloroben representatives stated that the lines should be cleaned mechanically.

The city decided, however, to proceed as originally planned on two of the lines, by setting up stations for regular Cloroben dosage at the upper ends of the lines. Treatments were started in Ross and Birch on May 28 and June 4, at a rate of $\frac{3}{8}$ g.p.d. Cloroben in each line. The average concentrations at the lower ends of the lines were estimated (on the basis of an assumed flow of 160 g.p.d. per residence) to have been 37 and 42 p.p.m., but the momentary concentrations must have varied from approximately 5 p.p.m. up to several hundred p.p.m. at the lower ends, and correspondingly higher concentrations toward the upper ends. The sulfide tests on following days, as shown in Table II, indicate some diminution of sulfide generation, particularly when the seasonal trend is considered.

On July 2, the Ross St. line was cleaned with a ball. Sulfide readings

TABLE II.—Cloroben Tests in Santa Ana, Calif.[1]

Date (1947)	No. of Tests[2]	Item	Sycamore	Broadway	Birch	Ross	Van Ness
May 1–9	10 to 13	Av. sulfides	T.S. 2.0 D.S. 1.3	T.S. 2.5 D.S. 1.4	T.S. 3.1 D.S. 1.8	T.S. 4.2 D.S. 2.6	T.S. 3.3 D.S. 2.4
May 12	—	Treatment	1 gal. Cloroben	1 gal. Benoclor 3S	Flushed	2.5 gal. Benoclor 3S	1.25 gal. Benoclor 3S
May 14–16	3	Av. sulfides	T.S. 0.8 D.S. 0.3	T.S. 1.5 D.S. 0.9	T.S. 2.1 D.S. 1.7	T.S. 2.8 D.S. 2.2	T.S. 3.2 D.S. 2.3
May 19–28	6 to 9	Av. sulfides	T.S. 1.9 D.S. 1.2	T.S. 2.4 D.S. 1.5	T.S. 4.0 D.S. 2.9	T.S. 4.5 D.S. 2.9	T.S. 3.9 D.S. 3.1
May 28-June 4	—	Treatment	—	—	Started Cloroben Av. 42 p.p.m.	Started Cloroben Av. 37 p.p.m.	—
June 4–18	5	Av. sulfides	—	—	T.S. 2.8 D.S. 2.1	T.S. 3.9 D.S. 3.0	—
June 18	—	Treatment	—	—	Stopped	Stopped	—
July 2	—	Treatment	—	—	—	Cleaned with ball	—
July 7–16	7	Av. sulfides	—	—	—	T.S. 0.3	—
July 21-Aug. 4	6	Av. sulfides	—	—	—	T.S. 2.0	—
Aug. 4	—	Treatment	—	—	—	Started Cloroben Av. 15 p.p.m.	—
Aug. 6 and 16	6	Av. sulfides	—	—	—	T.S. 2.7	—

[1] T.S., total solids; D.S., dissolved solids.
[2] Number of samples analyzed for each average result shown.

TABLE III.—Summary of Observations

Location	Cloroben Dosage[1] (p.p.m.)	Results
North Long Beach	1[2]	Unusually complete data indicate Cloroben to be without effect.
Los Angeles	1[2]	Sulfides not eliminated; available information indicates Cloroben caused little or no diminution.
Ventura	1[2]	Sulfides not eliminated; some reduction is indicated, but data too meager to permit this to be determined with certainty.
Buena Park collecting system and force main	3[2]	Data indicate Cloroben to be without effect.
Orange	1.25 to 10[3]	Sulfides not eliminated; data do not show whether there was any diminution.
Santa Fe Springs	5	Cloroben had no apparent effect in 3-day trial.
Santa Fe Springs	50	Cloroben had no apparent effect in 2-hr. trial.
San Gabriel force main	0 to 85[4]	Sulfides not eliminated, but moderate reduction (estimated 37 per cent) is indicated.
Laterals in Santa Ana	Varying with flow from a few p.p.m. to several hundred p.p.m.; average 15, 37, and 42 p.p.m.	Sulfides not eliminated. Reduction of something less than 50 per cent is definitely shown for the higher dosages; no effect evident at 15 p.p.m.

[1] Concentration in the total flow at the downstream test point; local upstream concentrations are in some cases much greater.
[2] Average.
[3] Daily average.
[4] Average 35 p.p.m.

were zero until July 10, and the average until July 16 was only 0.3 p.p.m. By the end of July this had risen to about 2.0 p.p.m. On August 4, Cloroben treatment was started at an estimated average dosage of 15 p.p.m., but tests on August 6 and 16 show no evidence of beneficial results.

The city also tried Cloroben in a lateral on French St. between 17th St. and Washington. This line is four short blocks in length in a completely developed residential area. Sulfide tests on July 21 and 22 showed 3.2 and 3.3 p.p.m. Application of 0.3 g.p.d. at the upper end was started on July 23. Four tests during the next week at the lower end showed sulfides averaging 2.9 p.p.m.

Summary

Table III collects the pertinent facts from the preceding eight cases.

Acknowledgments

In the assembling of the information contained herein, the writer is greatly indebted to those who have contributed data and who have assisted with the investigation—notably, representatives of the Los Angeles County Sanitation Districts, the Orange County Joint Outfall Sewer, City of Santa Ana, City of Los Angeles, City of Long Beach, City of San Buenaventura, the Santa Fe Springs Waste Water Disposal Co., and the Los Angeles Chemical Company.

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DISCUSSION

By Rolf Eliassen

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The results of the tests reported by Pomeroy are a significant contribution to the available literature on sewer line maintenance. Extensive data are presented to cite the conditions under which Cloroben will not be effective in suppressing the formation of sulfides in sewers. It is important that the data be analyzed to learn why the chemicals did not work in the places observed by Pomeroy and to compare these with the conditions which prevailed in places where the chemicals have been shown to be effective.

In studying the data of Pomeroy, it is apparent that short-term dosages of Cloroben do not lead to success, even though applied in the laterals. The tests at San Buenaventura, Santa Fe Springs, Santa Ana, Buena Park, and Orange City were all of short duration, ranging from two hours to ten days. It is known that sewer slimes and the state of the sewage, whether septic or fresh at the time of chemical application, are extremely important in determining whether sulfides will be generated in sewers. Slimes may take a considerable time to be removed by chemicals such as the organic chlorine compounds. That they can be removed in such a manner has been shown by Brown (1) and Beardsley (2) in Los Angeles.

Data from the City of Los Angeles presented by Pomeroy are rather complete and speak for themselves. Several factors have undoubtedly contributed to the reduction of sulfides there, but these factors cannot readily be evaluated individually.

In Long Beach, Cloroben was applied for extensive periods. Sulfide generation was not great, with and without Cloroben, and no significant differences could be noted with such small concentrations of sulfides. It is unfortunate that more data were not available on the growth of slimes on sewer walls and the oxidation-reduction potential of the sewage at the place of Cloroben addition and at the lower ends of the line where sulfides were measured. Starkey has shown the great influence of oxidation-reduction potential on the activity of *Sporovibrio desulfuricans*; the writer and his colleagues have shown (3) that Cloroben is not effective on this organism, which thrives at potentials in the range from -200 to -300 millivolts, but is effective against other organisms prevailing at higher potentials.

In addition to learning of the conditions under which Cloroben will not be effective, it is equally important to know where it will be effective in suppressing sulfides. Results previously presented (3) by the writer and his colleagues have indicated under what conditions organic chlorine compounds can be made to suppress sulfides in the laboratory. Results soon to be reported were obtained during the past year by Joe Williamson, Jr., in two Florida cities. This work has definitely shown that laboratory results can be duplicated in sewer systems and that effec-

tive suppression can be achieved if the necessary conditions established by laboratory research are made to prevail in the field. Considerable further study is necessary to correlate laboratory and field operation in order to provide the sanitary engineering profession with the necessary information to apply these chemicals successfully and to learn of the broad limitations in their use.

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DISCUSSION

By Herman Seydel and Albert H. Reiners

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The time covered in the results presented by Pomeroy encompasses practically everything since Cloroben was first introduced on the West Coast. This early work was largely exploratory and experimental and some results were bound to be less than satisfactory. The same can be said about any chemical treatment. All have their limitations and the determination of the necessary conditions for favorable results is not accomplished without errors.

Any new idea or material meets with a varied reception; it is hailed by some as a miracle and condemned by others as useless. Such opinions are largely due to fortuitous circumstances. These are modified by time and experience, which are necessary to develop the true worth of the commodity and determine its field of usefulness.

The laboratory work referred to (1) consisted of bottle experiments in sewage and a synthetic medium with various quantities of reagents. Results were charted as toxic dosage *vs.* time for sulfide concentration to reach 10 p.p.m. More than 48 hr. were required by the control and the test continued for two weeks.

Subsequent tests under practical conditions in the sewers of Los Angeles (2) showed that 1 to 2 p.p.m. of Cloroben inhibited sulfide formation in flowing sewage with a maximum flow time of 18 hr.

Eliassen, Heller, and Kisch (3) confirmed these results in carefully controlled laboratory work and found that coliform and other organisms in fresh sewage produce sulfides from organic sulfur compounds, that such sulfide production can be controlled by small dosages of Cloroben, and that a 75 per cent inhibition of sulfide production may be achieved for 18 hr. at 37° C. in fresh domestic sewage with 1 p.p.m. Cloroben. Under septic conditions, with the oxidation-reduction potential lowered to − 200 or − 300 m.v., *S. desulfuricans* reduce sulfates to sulfides and Cloroben is not effective against this type of sulfide organism. Eliassen's work confirmed the results found in practice and outlined the necessary conditions for sulfide control with Cloroben.

The accumulated septic sludge in force mains rapidly consumes all oxygen and fosters sulfide production from sulfates. The results in the San Gabriel force main in 1942, where a 37 per cent reduction in sulfides resulted from Cloroben treatment, can be interpreted as showing Cloroben to have been fairly effective.

Pomeroy's discussion of the condi-

tions in the City of Los Angeles provides a prewar picture of that city's struggle with the sulfide problem. Los Angeles' postwar experience with Cloroben led to a thorough investigation, which resulted in its methodical application throughout the city sewerage system.

In a paper presented by Reuben F. Brown and John T. Young at a meeting of the Sanitary Section of the American Society of Civil Engineers in Los Angeles in May, 1946 (*Western City*; May, 1946) they reported:

"It (Cloroben) is applied at the upper ends of sewer lines while the sewage is still fresh. Formation of hydrogen sulfide is retarded and the sewage remains comparatively fresh and putrefaction is delayed.

"Hydrogen sulfide production is reduced to less than 1 p.p.m. or to only a trace.

"Greases, slimes and bacterial growths which adhere to the sides of the sewer lines have been removed by the steady daily application of the chemical until the sides of the pipe become as clean as when originally constructed.

"Forced ventilation and aeration of large outfall sewers becomes unnecessary as sewer gas is produced only in very limited quantities when the chemical is properly applied. Thus, the destructive effects of the sewer gas on the pipes and structures of the sewerage system are very greatly reduced."

Brown (2), reporting on up-sewer Cloroben treatment of Los Angeles sewage, during which the Los Angeles Bureau of Standards analysed over 18,000 samples, found:

"One of the most interesting results of the experimental program was to observe that, as a result of the up-sewer treatment, the formation of hydrogen sulfide was inhibited to a large degree. A number of years ago studies on the trunk sewer lines discharging into the outfall sewer indicated that the hydrogen sulfide content of the sewer was as high as 25 p.p.m. in some sewers. Other sewers contained 1.5, 5.0, and even 10 p.p.m. of hydrogen sulfide. The outfall sewer at Hyperion contained an average of 2.25 p.p.m.

"When the full-scale experimental dosage of the entire sewer flow was adopted, it was found that the individual sewers contained from but a trace to 0.6 p.p.m. of hydrogen sulfide in the sewers and the sewage at Hyperion outfall contained approximately 0.2 p.p.m. hydrogen sulfide on the average (0.09 to 0.27 p.p.m.). Thus, the hydrogen sulfide content of the total sewage flow at Hyperion had been reduced by 91.6 per cent."

Pomeroy offers no new data contrary to Brown's report quoted above nor to his conclusion that:

"Organisms which produce hydrogen sulfide are either killed or otherwise interfered with, so that hydrogen sulfide production in long trunk sewers is reduced by 65 to 95 per cent."

Los Angeles may have discontinued the use of Cloroben for other reasons, but all available evidence shows that it rendered excellent service in controlling sulfides.

Practical applications for odor and sulfide control have produced satisfactory results in many cities. The list comprises over 100 municipalities and Oklahoma City, Okla.; Springfield, Mo.; Houma, La.; and Wichita, Kan., have reported their results.

In a great many of the unreported cases no analytical data is available to establish the relative conditions before and after this treatment. The sulfide odors were strong before Cloroben application and were absent, or not apparent, thereafter. Such practical evidence is satisfactory to the engineer or operator in charge, who generally has many other duties that require attention and lacks time for the meticulous collection of detailed data demanded by the critics.

Taylor (4), at Oklahoma City, reported:

"Odors were reduced to where they were hardly noticeable; hydrogen sulfide was practically eliminated."

Hazlip (5) at Houma, La., found that Cloroben added at the pumping sta-

tions prevented the odors due to septic sewage and was useful in the operation of an overloaded plant for the same purpose. He states that few chemical tests are made, sight and smell being the indicators used in operation. Gary (6), reporting on the same system, stated that with 2 p.p.m. Cloroben, the sewage arrived at the plant odor-free and non-septic.

In the opinion of the many operators who have found Cloroben helpful in reducing sulfide odors, that fact is the only essential. The tests necessary to substantiate their opinion are frequently beyond the facilities at their command. In fact, many of the efforts to devise tests and reproduce practical conditions in laboratory experiments have failed because of the complex nature of sewage and a lack of comprehension of the controlling factors. Negative results are strong indications that the method may be more faulty than the material. Practical tests in the sewage systems are frequently invalidated by the neglect of some obscure factor or condition.

Boyer in a private communication (July, 1948) on the tests at San Diego, found that where sulfides did not decrease after up-sewer Cloroben treatment, there were long unclean force mains in most cases; when these were flushed clean a satisfactory reduction in sulfides resulted from the treatment.

It seems only fair to point out that the negative results tabulated by Pomeroy could possibly be due to some undetermined factor which was not revealed or found while the tests were in progress.

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CONTAMINATION OF VEGETABLES GROWN IN POLLUTED SOIL *

II. FIELD AND LABORATORY STUDIES ON *ENDAMOEBA* CYSTS

By Willem Rudolfs, Lloyd L. Falk, and Robert A. Ragotzkie

In a previous paper (5) it was shown that such disease producing organisms as the *Salmonella* and *Shigella* species survived only a comparatively short time when applied to vegetables growing in the field. It is believed that one of the principal reasons for the relatively short survival is the lack of resistant resting stages of these organisms. In the case of the parasitic amoeba, *Endamoeba histolytica*, more or less resistant stages as cysts are formed, which enable the organism to survive under adverse conditions. These stages are passed in the feces of the infected person and, through irrigation with polluted water or the direct use of night soil as fertilizer, may reach the edible portion of the plants. Direct ingestion of the developed cyst is the manner whereby these parasites are transmitted from host to host.

In the course of fertilizing crops with night soil or irrigating fields with polluted water there is a real possibility of contaminating vegetables with *E. histolytica* cysts. Amoebic dysentery or chronic amoebiasis, or both, could be spread by human consumption of such contaminated vegetables.

It has been shown by Dobell (2) that the cysts of *E. histolytica* are not infective to humans until they have been cooled to room temperature for 24 to 48 hr. No morphological changes take place during this period, but apparently physiological changes occur that render the cysts capable of excysting when placed in the proper environment at body temperature. Most farming practices automatically allow for this period of physiological maturation by means of storage of night soil and time of transit of polluted water.

It is assumed that the cysts, if they reach the surface of field-grown vegetables at least one day after passage from the infected source, will be viable and physiologically mature. The problem is how long the vegetables would be dangerous after contamination. If the cysts survived for a week or two or even a month, decontamination would be necessary before vegetables could be consumed raw. On the other hand, if the cysts perished in a relatively short time, decontamination from the standpoint of this particular parasite would be unnecessary. Laboratory and field survival studies of *E. histolytica* cysts were conducted with these points in mind.

General Methods of Study

Selection of a Suitable Protozoan Parasite

In studies of this type, it is desirable to use a non-pathogenic organism, if possible. *Endamoeba coli*, a harmless commensal of the intestinal tract, was tried first as the test organism. There are three primary requirements for a cyst-forming protozoa which is to be used for survival studies: first, the amoeba must be readily culturable in order to obtain large numbers of amoebae in relatively high concentrations; second, it must be possible to induce cyst formation of the amoebae at will; third, excystation must be readily obtainable in order to demon-

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strate the presence of viable cysts by the resulting active cultures.

Several sources of *End. coli* were found, but all attempts to culture the organism failed. Dobell (3) (4) has cultured *End. coli* from monkeys and a marmoset. In regard to this amoeba, he says, "*E. coli* is, indeed, more difficult to cultivate properly than any other amoeba living in man; and to obtain pure cultures—free from all other species—in which active multiplication and encystation and excystation can be obtained regularly at will, is so difficult that nobody appears to have succeeded in the attempts hitherto." On the basis of this statement and the culture attempts made, *Endamoeba histolytica* was chosen as a test organism. This amoeba is known to be readily culturable, and results obtained by using it would be of greater value than those obtained with *End. coli*.

Production of E. histolytica *Cysts*

E. histolytica can be cultured by any of several methods. The Locke solution-egg slant medium of Boeck and Drbohlav was used for this study because of its simplicity and flexibility in inducing encystation and excystation.

The medium is composed of an egg slant in a test tube with an overlying layer of Locke's solution. The egg slant is made by mixing together 270 ml. of whole eggs and 75 ml. of Locke's solution. The well-beaten mixture is deaerated by vacuum pump, tubed, and inspissated by steam at 100° C. for 15 min. in a slanted position. Enough Locke's solution is added to each tube to completely cover the slant, and the tubes are autoclaved at 15-lb. pressure for 15 min. After sterilization approximately 30 mg. of rice starch are added aseptically to each tube. The medium with starch (R±) is then inoculated with *E. histolytica*. Transfers are made every 48 hr. by means of Pasteur pipettes, 0.5 ml. of the previous culture being added to each subculture. The amoebae multiply fairly rapidly in this medium and produce a small percentage of cysts at a regular rate.

To produce cysts in high concentrations the medium is used without starch (R−). Transfers are made from R to R− medium. These R− cultures are subcultured and increased in number by doubling the number of tubes at each transfer. No cysts are produced in the R− medium. After 5 or 6 cycles the amoebae are put back in R medium, 3 R− cultures being concentrated in each R tube. The R tubes are incubated for 72 hr., during which time most of the trophozoites encyst. The cysts are harvested by centrifuging the liquid portion of all the R− tubes. High concentrations of quadrinucleate (morphologically mature) cysts are obtained by this method. The cysts are counted by use of a Levy-Hausser haemacytometer and suspensions of any desired concentration obtained by dilution in Locke's solution.

One other requirement of *E. histolytica* in vitro is the proper bacterial flora, which includes at least 5 species. The bacterial population is maintained automatically by the frequent transfers necessary.

Evaluation of the Viability of Cysts

Both the laboratory and field cyst survival studies were based on culture methods. The vegetable surfaces were contaminated with mature, viable cysts. After various intervals, pieces of the contaminated vegetable skin were used as inocula in tubes of medium to determine the viability of the cysts.

Portions of tomato surface were marked off in approximately 1 sq. cm. areas, and were contaminated with known numbers of cysts in Locke's solution alone or in a feces-Locke's solution suspension. The controls were run by inoculating the cyst suspension directly into culture tubes. The inoculated tubes were incubated at 37° C.

for 48 hr. and then checked for an active culture by microscopic examination. If the culture was negative, it was transferred and re-incubated for 48 hr. Two transfers were made; if the third tube was still negative the sample was considered to contain no viable cysts. Later, this method was modified to a single transfer after 72-hr. incubation and two microscopic examinations. An active culture of amoebae at any stage was taken as proof that viable cysts existed on the sample.

Since a specific bacterial flora is necessary for the development of *E. histolytica* cysts in vitro, the tubes of medium which were to receive the unknown contaminated samples were inoculated with a culture of the required bacteria 24 hr. before sampling. To obtain an amoeba-free culture of the required bacteria the liquid portion of a stock amoebae culture was centrifuged to remove all amoebae and cysts from suspension. Transfers were made from the supernatant and after several sub-culturings examined for *E. histolytica*. It was found that this method yielded amoeba-free cultures of bacteria in all cases.

Number of Mature Cysts Required to Produce a Positive Culture

To evaluate the sensitivity of the previously described culture method of study, an experiment was conducted to determine the lowest number of mature cysts required to produce an active culture. A harvest of cysts was evaluated by use of the Levy-Hausser haemacytometer and found to contain 16,500 cysts per ml. Only mature, quadrinucleate cysts were counted. A series of dilutions were made, and inoculated into R culture tubes. These tubes were inoculated and examined by the usual method. Table I gives the results, showing that 20 or more cysts produced an active culture in all cases and in one case an active culture was produced by only 8 cysts.

TABLE I.—Number of *E. histolytica* Cysts Required to Produce a Positive Culture

Tube	Dilution[1]	No. of Cysts	Result of Culture
1	1:10	1,650	+
2	1:100	165	+
3	1:200	83	+
4	1:400	41	+
5	1:800	20	+
6	1:1,000	16	−
7	1:2,000	8	+
8	1:4,000	4	−
9	1:8,000	2	−
10	1:16,000	1	−

[1] Initial cyst concentration, 16,500 per ml.

Viability of Cysts in the Laboratory

Experiments were designed to study the effect on survival of drying and addition of organic matter in the form of feces. Pieces of tomato were cut and placed skin side up on glass microscope slides. On each piece a 1-sq. cm. area was marked off and surrounded with a paraffin dam. Known numbers of cysts were placed on each localized area. Control tubes were inoculated with the cyst suspension directly. The other contaminated samples were placed in culture tubes after varying intervals of time to determine the point where the cysts ceased to be viable.

The contaminated samples were allowed to dry normally in the laboratory and were dried rapidly by use of an electric fan. The samples were contaminated with cysts in suspension in plain Locke's solution and in Locke's solution mixed with feces.

Viability of Cysts in the Field

The field studies were designed to simulate the most favorable conditions possible for contamination of crops by *E. histolytica*. Both tomatoes and lettuce were used as test crops.

Contamination was accomplished by the following methods:

1. Small depressions in the soil were flooded with enough cyst suspension to supply 25,000 to 50,000 cysts, and to-

matoes were set in these depressions immediately.

2. Artificial cracks were cut radiating from the stem end of the tomatoes. These cracks were contaminated with cyst suspension, which in all cases amounted to 10,000 or more cysts per crack.

3. Natural, radial cracks in tomatoes were contaminated in a similar manner.

4. Leaf lettuce was contaminated by pipetting a concentrated suspension of the cysts down into the heart of the individual lettuce plants.

These methods of contamination provided the most favorable conditions of shade and moisture and exposed the contaminated parts to a minimum of desiccating influences. The duration of the contamination by *E. histolytica* was determined by cultural techniques. As in the laboratory experiments, the contaminated portions of the tomatoes were inoculated into culture tubes *in toto*. Where the tomatoes were set in contaminated depressions in the soil, the soil as well as the tomato was sampled to determine the duration of contamination of the soil itself. Contamination of the lettuce was evaluated by removing the entire plant from the ground and cutting off the underground parts and the uncontaminated portions of the leaves. The remaining stem and connected leaf bases were inoculated into prepared culture tubes.

Results

Laboratory Studies

In the laboratory the cysts were tested for survival on the smooth surface of tomatoes. Duplicate or triplicate samples were tested for each increment of time during the test. The culture method of evaluation was used exclusively.

In the tables of results the condition

TABLE II.—Survival of *E. histolytica* Cysts on the Surface of Tomatoes in the Laboratory

Sample Group	Time	Condition of Skin	Culture Result	Conditions
Control	0	—	+++	50 cysts per sample; in Locke's solution; dried normally; temp. 29° C.; humidity 45%
1	0	Wet	+++	
2	1 hr.	Wet	+++	
3	2 hr.	Dry	− − −	
4	3 hr.	Dry 1 hr.	− − −	
5	24 hr.	Dry 23 hr.	− − −	
Control	0	—	+++	50 cysts per sample; in Locke's solution; dried rapidly with fan; temp. 29° C.; humidity 45%
1	0	Wet	+++	
2	25 min.	Dry	+− −	
3	30 min.	Dry 5 min.	− − −	
4	40 min.	Dry 15 min.	− − −	
5	1.25 hr.	Dry 1 hr.	− − −	
6	2.25 hr.	Dry 2 hr.	− − −	
7	30 hr.	Dry 29.5 hr.	− − −	
8	48 hr.	Dry 47.5 hr.	− − −	
Control	0	—	+++	50 cysts per sample; in Locke's solution and feces suspension; dried normally; temp. 27° C.; humidity 40%
1	0	Wet	+++	
2	15 min.	Wet	+++	
3	60 min.	Wet	+++	
4	1.48 hr.	Dry	− − −	
5	2.10 hr.	Dry 6 min.	− − −	
6	2.15 hr.	Dry 10 min.	− − −	
7	2.20 hr.	Dry 15 min.	− − −	
8	2.25 hr.	Dry 30 min.	− − −	
9	2.50 hr.	Dry 60 min.	− − −	

of the tomato skin is noted in each case to show the correlation of viability with drying. Each sample tested is described by a plus (+) sign or positive culture and minus (−) sign or negative culture. A sample was considered to be contaminated with respect to *E. histolytica* if any one of the serial sub-cultures made from it was positive.

The effect of drying on the survival of *E. histolytica* cysts is illustrated by the results in Table II. When the contaminated samples were allowed to dry naturally, some cysts survived for 1 hr., but none survived for 2 hr. If the samples were dried rapidly by use of an electric fan, some cysts survived for 25 min., but no cysts survived as long as 30 min. In both cases the time of drying is very closely correlated with survival time of the cysts.

The results of cyst survival when feces are incorporated in the suspension indicate that drying had more effect on cyst survival than did total time after contamination. The results are similar in that drying time corresponded exactly to the survival time of the cysts.

Field Studies on Tomatoes

The results of contaminating artificial and natural radial cracks in tomatoes growing in the field with cysts of *E. histolytica* are given in Table III. Prevailing weather is included in these data for the possible effect it may have had on the survival of the cysts. Fifty per cent of the artificial cracks contaminated still contained viable cysts after 18-hr. exposure. None of the natural cracks held viable cysts after 18 hr. In no case were viable cysts recovered from radial cracks after 42-hr. exposure.

TABLE III.—Survival of *E. histolytica* on Tomatoes Growing in the Field

Mode of Contamination	Time (hr.)	Result of Culture	Weather
Artificial crack	0		Showers, cloudy
Artificial crack	18	+ −	Warm, clear, humid
Artificial crack	42	− −	Same
Artificial crack	72	− −	Same
Natural crack	0		Warm, clear, humid
Natural crack	18	− −	Same
Natural crack	42	− −	Same
Natural crack	66	− −	Same

TABLE IV.—Survival of *E. histolytica* on Tomatoes in Contact with Contaminated Soil in the Field under Wet and Dry Conditions

Location of Contamination	Time (hr.)	Culture Results	Condition of Soil
Control	0	++	Wet
Tomatoes	18	++	Wet
Soil	18	++	Wet
Tomatoes	42	+−	Wet
Soil	42	+−	Wet
Tomatoes	72	−−	Damp
Soil	72	−−	Damp
Control	0	++	Dry
Tomatoes	18	++	Dry
Soil	18	−−	Dry
Tomatoes	42	−−	Dry
Soil	42	−−	Dry
Tomatoes	66	−−	Dry
Soil	66	−−	Dry

Even more favorable conditions for cyst survival were tested by setting the tomatoes in a depression in soil soaked with a suspension of 25,000 to 50,000 mature cysts. The results of these tests are given in Table IV. Viable cysts were recovered after 42 hr. from both the tomatoes and the contaminated soil when the soil was wet. Later in the summer, when the soil was dry, viable cysts were recovered after 18 hr. from the tomatoes only. In no case did the cysts remain viable for as long as 72 hr. In comparison with the survival of cysts in cracks in the tomato itself, the more favorable moisture conditions afforded by wet soil prolonged the survival time by 24 hr.

Field Studies on Lettuce

The results of sampling and evaluating lettuce which had been contaminated with *E. histolytica* cysts are given in Table V. Soil condition is noted for all samples for any effects this may have had on the humidity in the im-

mediate proximity of the lettuce plants and consequently on the survival of the cysts. Viable cysts were recovered from all of those lettuce plants sampled after 18-hr. exposure when the soil was wet and from none of the plants sampled after 18-hr. exposure in dry soil. In no case were viable cysts recovered from contaminated lettuce exposed 48 hr.

Discussion of Results

The cystic stage of the life cycle of the enteric parasite *Endamoeba histolytica* must be understood in order to interpret properly the results of the survival studies. The cyst is produced in the intestine of the infected carrier. In the process of maturation the nucleus divides twice to form a quadrinucleate cyst. These nuclear divisions usually occur before the cyst leaves the body, but may take place outside the human body under optimum conditions of moisture and temperature. These quadrinucleate cysts become infective only after cooling to room temperature for 24 to 48 hr. Excystation will not occur until the cysts are placed in a favorable environment at 37° C., such as the human intestinal tract. In the process of excystation a single quadrinucleate amoeba emerges. As the cystoplasm divides, each nucleus divides again, thus producing eight amoebae from each cyst. The cysts of *E. histolytica* may be considered to be not only a resting stage, but also a reproductive stage. They are not highly resistant to the external environment as are the cysts of free-living amoebae. Excluding cysticidal agents, their time of survival outside the normal host, man, is dependent on the environmental factors of temperature and moisture.

In the laboratory studies it was found that the time of survival of the cysts corresponded very closely with the drying time of the contaminated sample. Whether the cysts were offered the additional protection of fecal material or merely placed on the samples as an inorganic suspension in Locke's solution made no difference in the time required for the cysts to perish. Apparently, not enough water was held by the fecal material to prevent desiccation of the cysts. Variations in drying time produced corresponding variations in survival time. On the basis of these laboratory studies it may be stated that the cysts are extremely sensitive to desiccation. With this fact in mind the field studies were conducted in a manner designed to minimize the effects of desiccation in order to study the effects of temperature and other miscellaneous environmental factors. In spite of these precautions, survival time seemed to follow rather closely the amount of moisture present on or near the contaminated portion of the tomato or lettuce.

When artificial and natural cracks were contaminated, the cysts in the artificial cracks remained viable for a short time (18 hr.), whereas those in the natural cracks were not recovered after the initial control samples. This was to be expected, as the artificial cracks probably remain moist for some time after being cut, whereas natural cracks are covered with rough, dry, protective coating, which prevents the juices of the tomato from reaching the

TABLE V.—Survival of *E. histolytica* Cysts on Leaf Lettuce in the Field under Wet and Dry Conditions

Time (hr.)	Culture Results	Condition of Soil	Weather
Control	++	—	—
0	+++	Wet	Showers, cloudy
18	+++	Wet	Warm, clear, humid
48	− − −	Wet	Same
72	− − −	Damp	Same
Control	++	—	—
0	+++	Dry	Warm, clear, humid
18	− − −	Dry	Same
42	− − −	Dry	Same
66	− − −	Dry	Same

cysts. In a similar manner, the cysts placed in depressions in the soil under the test tomatoes were shown to remain viable for 42 hr. when the surrounding soil was wet, but perished after 18 hr. when the soil was dry during the time of the test.

It is significant that tomatoes placed in contaminated soil always became contaminated with cysts. The cysts remained viable on the tomatoes at least as long as in the soil itself and longer when the soil was in a dry condition. It is evident, therefore, that the link between contaminated soil and growing vegetables can be completed by direct contact. The transmission and spread of *E. histolytica* depends on many such links, of which the weakest is the most important one from the standpoint of public health.

The experiments carried out during the summer of 1949 showed that cysts survived no longer than three days. This summer (1949) was one of the driest on record in New Jersey. Whenever possible, survival tests were conducted when these drought conditions were least severe. For example, some tests were begun immediately after some rain had fallen. In spite of this, the clear skies and long hours of hot sunshine tended to produce unfavorable conditions for survival of cysts of such low resistance.

Conditions in tropical regions, especially during the rainy season, would probably lead to longer survival periods. Beaver and Deschamps (1) found that under optimum conditions the cysts survived 6 to 8 days in moist soil at temperatures ranging from 28° to 34° C. These values are probably a fairly good indication of the maximum time that cysts would survive in soil during wet seasons in tropical or subtropical regions.

The influence of climate on the survival of the cysts of *E. histolytica* is controlled primarily by the factor of desiccation. With this fact in mind, it is evident that the chain of events leading to the transmission of amoebic dysentery can most effectively be broken by allowing sufficient time between contamination of the soil and harvesting of the crops to exceed the time of survival of the cysts. In temperate regions one week of dry weather would suffice for this purpose. In both temperate and tropical regions during periods of frequent and heavy rains, the humidity would undoubtedly be consistently high enough to prevent rapid desiccation of the cysts. Under these conditions the natural survival period of cysts under optimum conditions would be the governing factor for harvest dates. As the cysts have been shown to survive 6 to 8 days in soil, at least two weeks between fertilizing with contaminating material and harvesting of crops would have to be allowed for the prevention of the transmission of amoebic dysentery by this vector.

Conclusions

On the basis of the laboratory and field studies on the survival of *Endamoeba histolytica* cysts, the following conclusions may be stated:

1. The cysts of *E. histolytica* are extremely sensitive to desiccation. Complete drying of a cyst suspension results in practically instantaneous death of the cysts.

2. The addition of organic matter in the form of a fecal suspension does not enhance the survival of the cysts by offsetting the influence of desiccation.

3. Crops growing in the field may become contaminated with *E. histolytica* cysts directly during the course of irrigating or fertilizing the soil with sewage polluted water or night soil, or they may be contaminated indirectly through contact with the polluted soil containing cysts.

4. Tomatoes and lettuce that have become contaminated with the cysts are spontaneously decontaminated within 3 days of dry weather after con-

tamination occurred. The time required for this spontaneous decontamination decreases with a decrease in the degree of wetness of the soil.

5. Field-grown crops subject to possible contamination with the cysts of *E. histolytica* may be considered safe for consumption raw if a period of natural decontamination is allowed between the last application of the polluting material and harvesting. In the relatively dry temperate zone a period of one week is sufficient, whereas two weeks should be allowed in the wetter tropical regions.

Summary

Laboratory and field experiments on the survival of *Endamoeba histolytica* cysts applied either in suspension or in conjunction with feces to tomatoes and leaf lettuce direct, or to soil in which the plants were growing, show that the cysts are extremely sensitive to desiccation. Addition of organic matter in the form of fecal suspensions does not enhance survival of the cysts. Crops growing in the field may become contaminated directly during the course of irrigation with sewage polluted water or night soil, or indirectly through contact with polluted soil. Contaminated tomatoes and lettuce are free from viable cysts within 3 days after contamination occurs, the time of decontamination decreasing with a decrease in the degree of wetness of the soil. Field-grown crops consumed raw and subject to contamination with cysts of *E. histolytica* are considered safe in the temperate zone one week after contamination has stopped and after two weeks in wetter tropical regions.

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Industrial Wastes

THE TREATMENT OF PENICILLIN WASTES*

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The discovery of penicillin is credited to Alexander Fleming, a Scotch scientist, who in 1929 found that gram-positive streptococci, pneumococci, staphylococci and some gram-negative cocci were sensitive to filtrates of broth cultures of the mold *Penicillium notatum*. He called the antibiotic substance penicillin. During the years that followed, penicillin was studied by several investigators, but for the most part it was forgotten until World War II prompted further study.

In 1940, Florey and Chain isolated the drug and one year later ran the first clinical tests on human beings. These and later tests showed penicillin to be an anti-bacterial agent of great efficacy against various pathogenic organisms, including those responsible for pneumonia, peritonitis, venereal diseases, meningitis, and blood infections.

Later, a new strain of *Penicillium notatum* was isolated, which unlike Fleming's, could be cultivated in submerged fermentations. This discovery later eliminated troublesome flasks and surface cultures and by 1943 had replaced them with deep fermentation tanks, making large-scale production possible. More recently, streptomycin, tyrothricin, aureomycin, and chloromycetin have been developed and are now commercially produced. It is expected that many other antibiotics will follow. In 1949, antibiotic sales totaled $170,000,000, giving an indication of the magnitude of this new industry.

Manufacture

Penicillin is now produced by the fermentation of the mold *Penicillium chrysogenum*. Fermentation is accomplished in a number of stages originating from a master culture, continuing to a pre-seed flask, a seed tank, and finally to a deep fermentation tank. In each case, the medium or broth (consisting of corn steep liquor, lactose, water, and mineral salts) is sterilized, cooled, and inoculated with the culture from the previous stage. The fermentation is continued for several days, during which sterile air is blown through the broth and the batch is constantly cooled to remove the heat of fermentation. Occasionally the culture becomes contaminated and the batch must be discarded.

The ferment liquor is removed from the tanks, the growth inhibited with formaldehyde, and the mold or mycelium is filtered off and discarded. The penicillin is extracted from the broth with organic solvents and is then refined, dried, and measured into vials. The broth is neutralized, distilled to remove remaining solvents, and is then discarded together with waste process waters.

Plant Wastes

The spent broth from penicillin manufacture has a solids content of about

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20,000 p.p.m. and a B.O.D. of 7,500 p.p.m. It consists primarily of proteins, sugars, and organic acids. The waste process waters include washings, spills, waste acid, caustic, and salts, unrecovered solvents, and laboratory drainage. They amount to 1.7 gal. per gallon of fermented broth and have a solids content of 8,000 p.p.m. and a B.O.D. of 3,000 p.p.m. The organic content of this waste is similar to that of the spent broth, but in lower concentration. The spent broth contributes 59 per cent of the B.O.D., the waste process waters contribute 40 per cent, and the sanitary wastes 1 per cent.

Contaminated batches are high in suspended material, primarily mycelium, and have a B.O.D. of about 12,000 p.p.m. However, as they are produced only occasionally and amount only to a few thousand gallons in volume, they are of relatively minor importance.

The mycelium has a solids content of 150,000 p.p.m. and a B.O.D. of 47,000 p.p.m. About 1 lb. of wet mycelium is produced for each gallon of fermented broth. It is a yellow semi-solid material and autolizes rapidly, forming a pulpy, odorous mass.

One of the considerations in penicillin waste disposal is the practicability of solids recovery by evaporation of the spent broth and drying with the mycelium. These solids have high nitrogen, carbohydrate, phosphate, and vitamin contents and amount to about 0.4 lb. per gallon of fermented broth. The economics of recovery depend largely upon the market value of the dried product as a poultry feed.

The solids recovery considerably reduces the strength and composition of the waste. However, the evaporate contains small quantities of volatile organics sufficient to result in B.O.D. values averaging 1,400 p.p.m. Evaporation removes 79 per cent of the B.O.D. from the spent broth, or 48 per cent based on the composite waste.

TABLE I.—Composition of Penicillin Wastes

Constituent	Raw (p.p.m.)	After Solids Recovery (p.p.m.)
B.O.D.	4,030	2,110
Oxygen consumed	4,050	1,430
Total solids	12,400	4,300
Volatile solids	7,150[1]	1,630[2]
Suspended solids	1,390	1,170
Total nitrogen	400	95
Total sulfur	429	82
Reducing sugars	943	187
Ammoniacal nitrogen	131	70

[1] 57.7 per cent of total solids.
[2] 33.9 per cent of total solids.

Without solids recovery, the combined liquid wastes have an average B.O.D. of 4,030 p.p.m., with a range from 1,020 to 11,000 p.p.m., and a solids content of 12,500 p.p.m. When recovery is practiced, the resulting B.O.D. averages 2,100 p.p.m., with a variation of from 750 to 5,800 p.p.m., and the solids content is 5,000 p.p.m. The characteristics of the two wastes are given in Table I. As indicated, there is a reduction in oxygen consumed, solids, nitrogen, sulfur, and sugar. However, these reductions are not proportional to that of the B.O.D. reduction. The oxygen consumed–B.O.D. ratio of 1.0 in the raw wastes is decreased to 0.68 after solids recovery. Similarly, the nitrogen–B.O.D. ratio in the raw wastes of 0.10 is reduced to 0.045 after solids recovery. Suspended solids remain constant and the percentage of volatile matter in the solids is reduced.

The Problem

The development of the submerged fermentation of penicillin in 1943 and subsequent large-scale penicillin production during the war gave rise to a difficult waste disposal problem. Some penicillin plants were located in large cities, where municipal sewage treatment plants offered no deterrents to the disposal of these wastes. However, plants located in small cities—and especially those located on watershed

areas—found the problem of waste disposal a serious one.

The Heyden Chemical Corporation's Princeton, N. J., plant fell into this latter group. The plant is located on the watershed of the Millstone River, which supplies water for several communities. The only immediate dilution available for these wastes was a small brook fed principally by waste cooling waters from the plant. About two miles farther downstream the brook enters the Millstone River at a point about 18 miles above a water intake.

The Millstone River is of high quality and is subject to low dry-weather flows. Under normal river flow conditions, the effect of the raw wastes on the river would not be detectable. However, under dry-weather conditions, the discharge of these wastes in any except a highly treated condition would impose a heavy pollution load upon the stream. The New Jersey State Department of Health, therefore, established a standard of 30 p.p.m. of B.O.D. for the treatment of these wastes. This represents a B.O.D. reduction of 99.3 per cent.

The original plans of the Heyden plant called for the installation of a subsurface irrigation system for the disposal of the wastes. Shortly after this system was completed, it proved unsuccessful; the impervious soil permitted but slight percolation. Lagooning was also tried, but resulted in a serious odor nuisance and was quickly abandoned. Simultaneously, laboratory experiments with waste treatment proved unsuccessful due to the toxic concentration of solvents in the wastes.

Subsequently, several sandy areas were located some distance from the plant. Trucking of the liquid industrial wastes in tank trucks to these areas was begun in October, 1943, and has been continued to the present, although operations have been alternated between various locations. The highly porous sandy soils of these disposal areas have afforded excellent rates of percolation and have provided a good means of temporary waste disposal. The percolated waste appears to have no effect on local streams or wells. However, the cost of this method of disposal is very high.

Preliminary Research

Equipment for the recovery of solvents from the penicillin wastes was later designed and placed into operation, thus reducing the solvent concentration in the wastes to below the toxic level and making biological treatment studies possible. Shortly thereafter, a laboratory research program was launched, in cooperation with Rutgers University, to determine suitable methods for the treatment of these wastes.

On the basis of the two-year experimental work it was concluded (1) that the penicillin wastes were strong and that there was considerable variation in the strength of the spent broth and process waters. It was recommended that the wastes be equalized to obtain a fairly uniform strength and that all solvents be removed to prevent retardation or inhibition of biological purification. There appeared to be no difference in the behavior of spent broth and process waters and they could be considered as the same type of material. The only effects were those connected with strength variation, which was common to both types of waste.

Digestion of the spent broth, process waters, or mixtures thereof, appeared feasible, but was believed economically unsound. Digestion required careful control and was recommended only for the sludge obtained from the various treatment units.

Aeration of the wastes with dispersed growths appeared practical and less costly than digestion. Aeration for a minimum period of 24 hr. was required to obtain high removals. Sand filters were found capable of reducing the B.O.D. of the effluent from the aeration unit to the required final effluent qual-

ity if loaded at not greater than 500 lb. of B.O.D. per acre per day.

However, advances in the manufacture of penicillin resulted in changing processes, making treatment studies difficult. Evaluation of the effects of wide variations in the character and rate of flow of the wastes and the absence of an effective method for the study of trickling filter treatment imposed additional problems on the laboratory studies.

These limitations indicated the need for experimentation on a continuous flow, pilot-plant scale. Accordingly, a pilot plant was designed by the writer for flows ranging from 1 to 30 g.p.m., including recirculation, and based on very conservative B.O.D. loadings. Construction was begun in the fall of 1946 and was completed in the spring of 1947 at a cost of $65,000.

Pilot Plant

The pilot plant consisted of a wooden building 65 ft. by 25 ft., which housed the laboratory, the 15 pumps, the electrical and flow control panels, five concrete sedimentation tanks, a chlorinator, and a chlorine contact tank; a small wooden building housing a blower and air metering equipment; two equalization tanks; a sand filter and dosing tank; two aeration tanks; two shallow trickling filters; one deep trickling filter; a sludge digester; and a sludge drying bed (Figure 1).

The pilot-plant design was based on a waste with a B.O.D. of 4,000 p.p.m. and a basic flow of 2 g.p.m. (2,880 g.p.d.). The aerators, trickling filters, digester, and sand filter were designed to provide treatment for up to 10 g.p.m. in the event that greater removals could be obtained than were anticipated. The laboratory investigations at Rutgers University were used as a basis for the design of the aeration and sand filtration units.

All flows were pumped from unit to unit with the exception of those to the sedimentation tanks, which were by gravity. Weirs were used to measure recirculated flows; rotameters were used to measure the flows from unit to unit. Air volumes were metered with orifices. Gas production from the digester was metered with a small gas meter. The piping was designed to handle the maximum flow rates, including any recirculated flows, and the piping arrangement at the panel board was made flexible to permit operation

FIGURE 1.—General view of pilot plant and storage tanks for penicillin waste treatment.

of the units in parallel, in series, and in various combinations.

The equalization tanks, each of 2,000-gal. capacity, provided for storage, neutralization, and primary clarification. Subsequently, continuous feeding and neutralization was substituted, with control by a pH recorder-controller.

Each of the two steel aerators provided for 12-hr. aeration. The tanks were baffled for spiral flow and were each 14 ft. long, 7 ft. deep, and 3 ft. wide, with a 6-ft. side water depth. Air was distributed through a series of porous diffuser tubes. A 70 per cent reduction in B.O.D. was anticipated after 24-hr. aeration; the effluent from these units would thus contain 1,200 p.p.m. of B.O.D. for a waste with an initial B.O.D. of 4,000 p.p.m., assuming no removal by primary sedimentation.

Two shallow trickling filters were constructed, with provision for either series or parallel operation with recirculation. The filters were expected to remove 50 per cent of the applied B.O.D. of 1,200 p.p.m. at a loading of 1.5 lb. of B.O.D. per cubic yard of stone. Two 9-ft. diameter filters were used, each with a 4-ft. depth of stone varying in size from 2 to 4 in. Two-arm rotary distributors were used, and filter tanks were constructed of 6-ft. high wood staves. Vent pipes were provided for each filter; forced ventilation was provided by air blown through a grid of perforated pipe beneath the filter (Figure 2).

FIGURE 2.—Shallow trickling filters of penicillin waste treatment pilot plant.

The deep trickling filter was designed for treatment of the primary trickling filter effluents with an estimated B.O.D. of 600 p.p.m. The loading was set at 0.15 lb. of B.O.D. per cubic yard of stone and the B.O.D. removal was anticipated at 65 per cent. The filter was 21 ft. in diameter and contained 8 ft. of stone varying in size from 1 to 2 in. A motorized "Aero-filter" disc distributor was used to distribute the waste at rates of from 0.4 to 6.0 m.g.a.d. over the filter. Vent pipes were provided, as were facilities for forced ventilation. This tank was also constructed of wood staves.

In order to further reduce the B.O.D. of the waste, a slow sand filter was provided. The filter was designed to treat the secondary filter effluent of 210 p.p.m. at a B.O.D. loading of 250 lb. per acre. A two-section filter, 30 in. deep and 30 ft. square (0.21 acre) was constructed, together with a dosing tank and two alternating siphons.

Chlorination for sterilization and color removal was included in the pilot plant and a hypochlorinator was installed for this purpose. The chlorine contact tank was of wood, tar coated, with over-and-under baffles, and was designed for a 30-min. contact period.

Five hopper-bottom, monolithic concrete clarifiers provided for sedimentation of the effluent from each aerator and trickling filter for 1-hr. detention periods at a 10-g.p.m. flow rate.

The digester was a steel tank 6 ft. in

diameter and 12 ft. high. It provided for a 30-day heated digestion period for the sludge, originally estimated at 2 per cent of the raw waste flow. Take-offs at 2-ft. intervals and a mixing mechanism were provided.

Pilot Plant Operation and Results

Operation of the plant was initiated in April, 1947. Studies were made with penicillin process waters separately and together with the spent broth. Studies were concluded in May, 1948, after 13 months of continuous operation, in which the units of the pilot plant were arranged in various combinations utilizing different flow, air, and recirculation rates; many B.O.D. loadings and strengths; and several detention periods. In all, some 60 combinations of treatment units and a wide range of conditions were studied.

Variations in pH within the range of 6 to 8 were found to have no effect upon the treatment, but values beyond that range resulted in reduced efficiencies. Primary sedimentation gave erratic B.O.D. reductions varying from 0 to 23 per cent, with an average of 10 per cent for a 4-hr. sedimentation period.

Optimum efficiencies with aeration were obtained with a 20-hour detention period and 30 per cent sludge return rate. With waste process waters of 2,100 p.p.m. B.O.D., a 95 per cent efficiency was obtained; with the combined waste of 4,000 p.p.m. B.O.D., an efficiency of 89 per cent was obtained. During the winter period the efficiency dropped about 20 per cent under similar operating conditions. The air rate required for these efficiencies was 3 cu. ft. per hour of aeration per gallon of waste treated, or 60 cu. ft. per gallon for the 20-hr. aeration period. However, although high B.O.D. removals were obtained with aeration, considerable foaming occurred, the effluent was turbid and difficult to treat on subsequent treatment units, and very large quantities of air were required.

Most satisfactory results were attained with deep and shallow trickling filters when operated at 15:1 recirculation ratios. Optimum efficiencies of 82 per cent were obtained with shallow trickling filters when loaded at 3 lb. of B.O.D. daily per cubic yard of filter, but during the winter season these efficiencies dropped to 42 per cent. Efficiencies of 97 per cent were obtained with the deep trickling filter at a loading of 0.2 lb. of B.O.D. daily per cubic yard of filter, dropping to 80 per cent at a loading of 1 lb. During the winter the efficiency of this unit dropped to 57 per cent under optimum loading conditions. The reduced efficiencies of the trickling filter during the winter were attributed primarily to the accelerated rate of cooling that took place at the 15:1 recirculation rates. The solution to this problem appears to be the use of lower recirculation rates during the colder weather.

Forced ventilation of the deep trickling filter improved B.O.D. efficiencies only when low recirculation rates were used. Sludge production from the shallow trickling filters was considerably higher than from the deep filter, based on the cubic feet of sludge per pound B.O.D. removed.

Sand filters provided optimum efficiencies of 85 per cent at loadings of 400 lb. of B.O.D. daily per acre (0.10 lb. per cubic yard) and with dosing rates within the range of 30,000 to 150,000 g.p.d. per acre. Clogging of sand filters occurred frequently, even at low loadings, when these units were used to treat aerator effluents. Clogging did not occur when trickling filter effluents were treated unless loadings in excess of 1,500 lb. per acre were applied.

During the pilot-plant experiments quantities of solvents could be detected in the waste. Erratic purification results that were obtained at times from certain of the treatment units were probably related to toxic solvent concentrations. This was evidenced by

unusually high effluent values obtained from several parallel treatment units operated simultaneously.

Digestion of the sludge from the various processes proceeded rapidly at a temperature of 75° F. when seeded with digested sludge, and was completed in 18 to 25 days, depending on its origin. Mycelium was found to digest satisfactorily in 25 days with a 1:4 volatile seed to raw ratio. Digestion of the raw waste gave extremely erratic results and a low order of B.O.D. removal.

Biological treatment was found to remove little of the 2,000-p.p.m. initial color of the raw waste. A 500-p.p.m. chlorine dosage was required for a 65 per cent color removal and a 1,000-p.p.m. dosage was required for a 95 per cent removal. Activated carbon required a 1 per cent dosage for complete color removal; coagulents were unsuccessful for this purpose.

A graphical summary of B.O.D. efficiencies is given in Figure 3, which indicates the optimum as follows: deep trickling filter, 97 per cent; aerator, 96 per cent; sand filter, 85 per cent; and shallow trickling filter, 82 per cent. The unit most effective at high loadings is the aerator, followed in order by the shallow, deep, and sand filters.

Figure 4 illustrates the B.O.D. removals per cubic yard of treatment unit capacity per day for various loadings. It is interesting to note that the absolute B.O.D. removals as indicated in Figure 4 all fall within a relatively narrow band of values. The deep filter gave the widest range of removals, whereas the aerator gave the highest removal per unit capacity.

Treatment Methods

Since waste process waters may be treated satisfactorily with either the spent broth or with the spent broth evaporate, the problem of penicillin waste disposal resolves itself into a comparative study of the economics of: (1) the treatment of all of the combined liquid wastes; and (2) by-product recovery followed by treatment of the remaining wastes.

Several combinations of units are available for the treatment of the liquid wastes. Each includes neutralization, primary clarification, biological treatment, chlorination, and separate

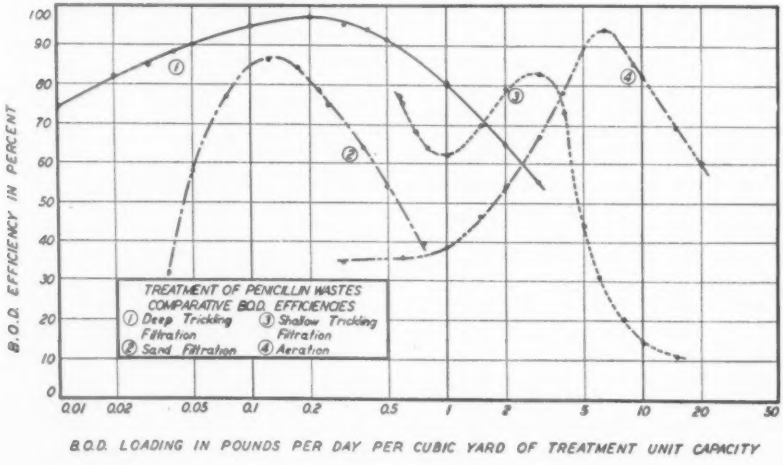


FIGURE 3.—Comparative B.O.D. efficiencies in penicillin wastes treatment.

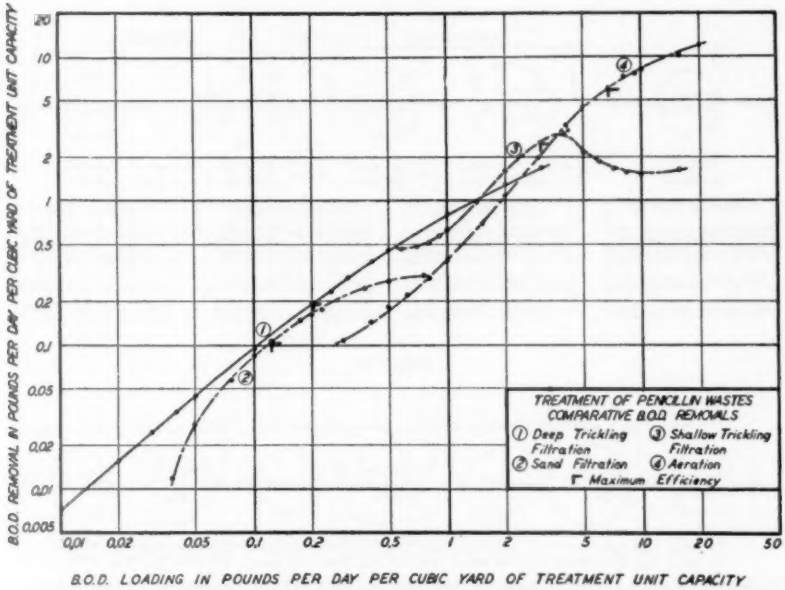


FIGURE 4.—Comparative B.O.D. removals in penicillin wastes treatment.

sludge digestion. Biological treatment combinations employing trickling filters offer fewest operating difficulties and lowest operating costs. The aeration and trickling filter units in each method require secondary clarification. These processes are as follows:

A. Shallow trickling filtration followed by deep trickling filtration.

B. Three-stage shallow trickling filtration.

C. Two-stage deep trickling filtration.

D. Deep trickling filtration followed by sand filtration.

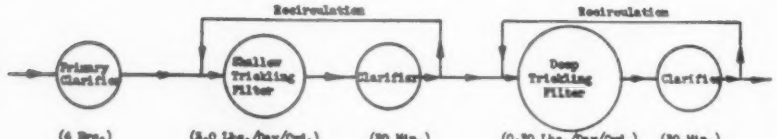
E. Two-stage shallow trickling filtration followed by sand filtration.

F. Aeration followed by deep trickling filtration.

These treatment processes are indicated in Figure 5 and are each capable of removing 99.3 per cent of the B.O.D. and of producing an average effluent of 30 p.p.m. from a raw waste of 4,030 p.p.m., whether or not preceded by solids recovery. These results are based on 15:1 recirculation of trickling filter effluents and 30 per cent sludge return in the aeration system.

Without recovery, 10 per cent of the B.O.D. is removed by primary clarification and 89 per cent by biological treatment. With by-product recovery, 47.7 per cent of the B.O.D. is removed by recovery, 5.2 per cent by primary clarification and 46.4 per cent by biological treatment.

Methods A, B, and C offer the lowest operating costs and most trouble-free operation. Method C offers greatest consistency of results, followed in order by A and B. Methods D and E offer higher operating costs, due to expensive sand cleaning and replacement. Clogging problems are encountered, but a good consistency of results is obtained. Process F offers low first costs, but has the disadvantage of severe foaming, high power consumption, and large quantities of sludge produced.



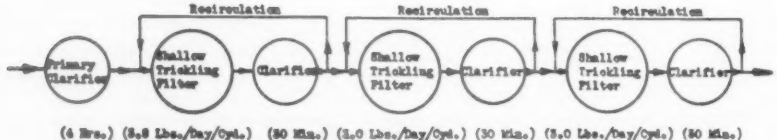
BY-PRODUCT RECOVERY			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4080	—	—	—
4080	2110	47.7	47.7

PRIMARY CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4080	3627	10.0	10.0
2110	1899	10.0	8.2

SHALLOW TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
3627	689	81.0	72.9
1899	360	81.0	38.2

DEEP TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
689	30	96.0	16.4
360	30	92.0	8.2

PROCESS "A"



BY-PRODUCT RECOVERY			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4080	—	—	—
4080	2110	47.7	47.7

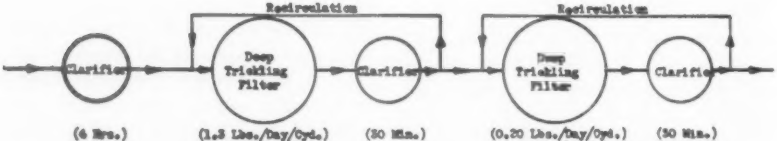
PRIMARY CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4080	3627	10.0	10.0
2110	1899	10.0	8.2

SHALLOW TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
3627	834	77.0	69.3
1899	495	75.0	35.0

SHALLOW TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
834	158	81.0	18.8
495	119	75.0	8.8

SHALLOW TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
158	30	81.0	3.2
119	30	75.0	2.2

PROCESS "B"



BY-PRODUCT RECOVERY			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4080	—	—	—
4080	2110	47.7	47.7

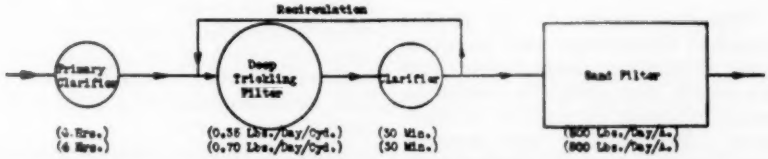
PRIMARY CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4080	3627	10.0	10.0
2110	1899	10.0	8.2

DEEP TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
3627	979	73.0	65.7
1899	512	73.0	34.4

DEEP TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
979	30	97.0	32.6
512	30	94.0	11.9

PROCESS "C"

FIGURE 5.—Processes for the treatment of penicillin wastes.



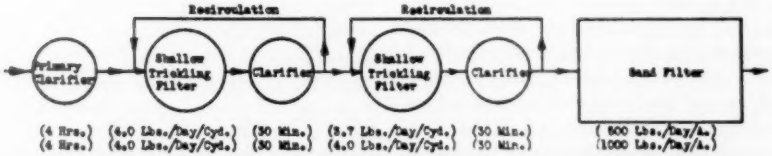
BY-PRODUCT RECOVERY			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4030	—	—	—
4030	2110	47.7	47.7

PRIMARY CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4030	3627	10.0	10.0
2110	1899	10.0	8.2

DEEP TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
3627	200	94.6	86.1
1899	200	89.5	42.2

SAND FILTER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
200	30	85.0	4.2
200	30	85.0	4.2

PROCESS "D"



BY-PRODUCT RECOVERY			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4030	—	—	—
4030	2110	47.7	47.7

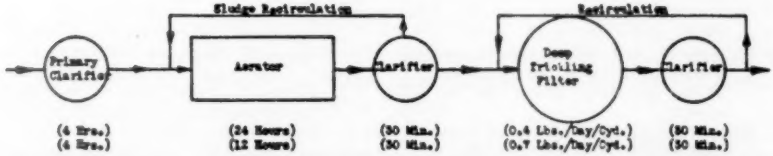
PRIMARY CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4030	3627	10.0	10.0
2110	1899	10.0	8.2

SHALLOW TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
3627	907	75.0	47.5
1899	475	75.0	25.6

SHALLOW TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
907	200	78.0	17.6
475	119	75.0	8.8

SAND FILTER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
200	30	85.0	4.2
119	30	75.0	2.8

PROCESS "E"



BY-PRODUCT RECOVERY			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4030	—	—	—
4030	2110	47.7	47.7

PRIMARY CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
4030	3627	10.0	10.0
2110	1899	10.0	8.2

AERATOR & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
3627	399	89.0	80.1
1899	190	90.0	42.4

DEEP TRICKLING FILTER & CLARIFIER			
Infl. (ppm)	Effl. (ppm)	Effic. (%)	Rem. (%)
399	30	93.0	9.2
190	30	84.0	4.0

PROCESS "F"

FIGURE 5 (continued).

Summary and Conclusions

Pilot-plant studies by the Heyden Chemical Corporation with numerous types of waste treatment indicate that the wastes from penicillin readily respond to almost all methods of treatment. Due to their high strength, however, special operating procedures and either two or three oxidation units are required. The addition of sanitary sewage to the industrial waste is necessary to provide the proper microorganisms for biological treatment. The nitrogen and phosphorus contents are sufficient for proper growth and no supplemental additions are necessary.

When only partial treatment is required, as in the case of discharge into a municipal treatment plant or a large body of water, short-period aeration offers the most economical method of treatment per pound of B.O.D. removed; but when complete treatment is required, shallow trickling filtration followed by deep trickling filtration offers the most satisfactory method, with lowest operating costs and minimum sludge volumes. However, the first cost may be lower with one of the other trickling filter combinations. The mycelium may be dried, treated by digestion, or buried. Superchlorination will effectively remove a substantial portion of the color.

It is felt that the expenditures for the construction and operation of the pilot plant have been more than justified by the development of several treatment methods, which could not have been adequately studied in the laboratory. These methods will produce over-all B.O.D. reductions as high as 99 per cent, with corresponding B.O.D. effluent values of 30 p.p.m.

This paper has been devoted only to a discussion of the wastes from the manufacture of penicillin. However, intensive study has been given to the treatment of streptomycin wastes alone and in combination with penicillin wastes. It has been found that the same general methods of treatment are applicable to both wastes, and it is expected that the wastes from the other antibiotics will follow similar trends.

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ADSORBENTS IN WASTE WATER TREATMENT—DYE ADSORPTION AND RECOVERY STUDIES

By H. A. Thornton and J. R. Moore

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In the postwar period, industry has become increasingly aware of the need to clean up waste effluents and reduce stream pollution and is taking an active interest in methods of waste treatment. The standards for the quality of a waste effluent are gradually becoming more rigid and a treatment considered entirely satisfactory a few years ago is often considered unsatisfactory today.

There are several types of waste materials that do not readily lend themselves to standard methods of waste treatment. Important among these are organic substances not readily treated by aerobic digestion, including:

1. Tars, oils, and greases.
2. Dyes.
3. Toxic chemicals.
4. Taste and odor producing substances.

Dyes are particularly difficult to remove by standard methods of waste treatment. They are unusually stable to light and oxidizing agents, and are resistant to aerobic digestion. In view of the successful use of fuller's earth and bauxite for the removal of color bodies and other impurities, particularly from petroleum products, use of these adsorbents for treatment of dye wastes has been investigated in the laboratory.

Granular fuller's earth and bauxite have been used for many years in large commercial filters for removing the color bodies from lubricating oils, waxes, and sugars (1). Some 70,000 tons of these materials are consumed per year in the process employing fixed adsorbent beds and repeated use of the adsorbent by thermal regeneration.

The successful large-scale use of adsorbents in the petroleum and sugar purification fields has encouraged consideration of their use in other fields. Strain (2) and Zechmeister and Cholnoky (3) refer to the use of these adsorbents in various phases of chromatography. Mutch (4) has found that many dyes in water solution are adsorbed by bauxite; Parsons (5) states that fuller's earth has a good capacity for adsorbing basic dyes from water solution.

This paper presents the results of a laboratory investigation of the dye adsorbing properties of two widely used, inexpensive adsorbents—fuller's earth and bauxite. Synthetic dye wastes used in the investigation contained dyes, acids, and salts commonly encountered in waste water from dye manufacture or textile dyeing operations.

Apparatus and Methods

Laboratory apparatus used for studying the adsorption of dyes from aqueous solution by granular adsorbents consisted of a vertical fixed-bed column fed by gravity flow from a 5-gal. bottle through a constant head device. The adsorbent column was a pyrex tube holding approximately 200 ml. of adsorbent supported on a glass wool plug in a constricted portion of the tube. Rate of flow was controlled by a stopcock at the outlet of the adsorbent column. A sketch of the ap-

paratus as used for upflow and downflow is shown in Figure 1.

In normal operation the percolation column was filled with dye solution and allowed to soak for 30 min. to displace all air. The flow of dye solution was then started and regulated to the desired space velocity as indicated by the rate of flow of effluent.

In most percolations a quantity of substantially dye-free effluent was produced initially, after which there was a break in the adsorption curve and the concentration of the dye in the effluent began to rise.

To determine the degree of dye removal, effluent liquid was analyzed for dye concentration by means of a Beckman spectrophotometer. The light adsorption was compared to that for standards of known dye content. Percolation was continued until the concentration of dye in the effluent reached one-half that of the initial. The adsorbent was then blown free of aqueous dye solution, using air, and was regenerated by one of several procedures, some of which involved dye recovery. The procedures used for regeneration are discussed hereinafter in the section on "Adsorbent Regeneration and Dye Recovery." All percolations were conducted at atmospheric pressure and room temperature.

With both fuller's earth and bauxite, a plot of the concentration of dye in effluent against the cumulative volume of percolated dye solution (volume

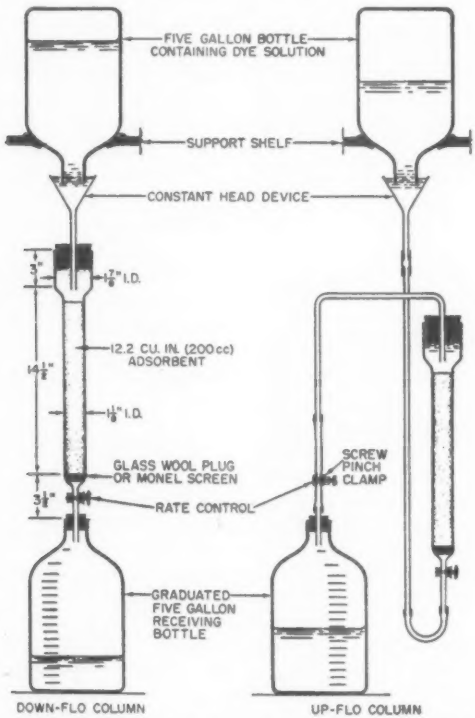

FIGURE 1.—Laboratory percolation columns for dye adsorption studies.

yield) gives a curve with a sudden break where dye adsorption begins to fall off. The intercept of the steep slope of the curve with the abscissa has been taken as the "end point" or "break point" of the dye adsorption cycle (see point D, Figure 2). This represents the volume of dye solution which may be adsorbed without appreciable dye concentration in the effluent.

Materials Used

Several aqueous dye solutions, which were thought to be representative of commercial spent dye liquors or wastewater effluents, were prepared. The solutions were prepared at a concentration of 200 p.p.m. of dye in distilled water. Acids or salts were added to approximate spent dye-bath conditions. The types and concentrations of prepared liquors were as follows:

Type of Dye	Dye[1] 200 p.p.m.	Acid or Salt
1. Mono azo acid	Calcocid orange Y	100 p.p.m. 98% sulfuric acid
2. Palatine mordant acid	Calcochrome brown RV	100 p.p.m. glacial acetic acid
3. Direct tetra-azo	Calcodur red 8 BL	10 p.p.m. sodium carbonate
4. Basic	Calcozine blue B	600 p.p.m. glacial acetic acid
5. Chrome-metallized	Calcofast wool yellow R	480 p.p.m. 98% sulfuric acid
6. Direct	Calcomine black	400 p.p.m. sodium carbonate 100 p.p.m. sodium chloride
7. Acid mordant	Calcocid green S	100 p.p.m. 98% sulfuric acid

[1] Dyes furnished by the Calco Division, American Cyanamid Company.

The adsorbent has considerable capacity for dye beyond the break point and most percolations were carried further to a point where the effluent dye concentration was equal to one-half that of the influent; that is, $C_e/C_0 = 0.5$, in which C_e is the concentration of dye in the effluent and C_0 is the concentration of dye in the influent.

The total dye adsorbed to the break point is approximately equal to the total dye in the influent. The total dye adsorbed to the $C_e/C_0 = 0.5$ end point is represented by the total dye in the influent less the total dye in the effluent.

These end points have been arbitrarily selected as a basis for comparing the performance of the various dyes and adsorbents tested. Commercially, adsorbent beds of greater depth are used than can be conveniently operated in a laboratory evaluation. Hence, somewhat improved results may be obtained in pilot-plant or commercial operation.

Some percolations were carried out with less concentrated dye liquors prepared by dilution of the 200 p.p.m. dye solution with distilled water. All dyes were completely soluble at room temperature in the concentrations studied.

The adsorbents used in the study were granular activated bauxite and granular Georgia-Florida type fuller's earth. The physical and chemical characteristics of the activated granular products are given in Table 1.

Discussion of Results

The dye adsorbing capacity of bauxite and fuller's earth for a number of dye liquors is given in Table II. The effect of space velocity on the quantity of dye adsorbed from two dye liquors is given in Table III. The effect of space velocity on the adsorption of Calcodur red 8 BL using activated bauxite is shown graphically in Figure 3. The effect of initial dye concentration on the quantity of dye adsorbed is given in Table IV, and part of this

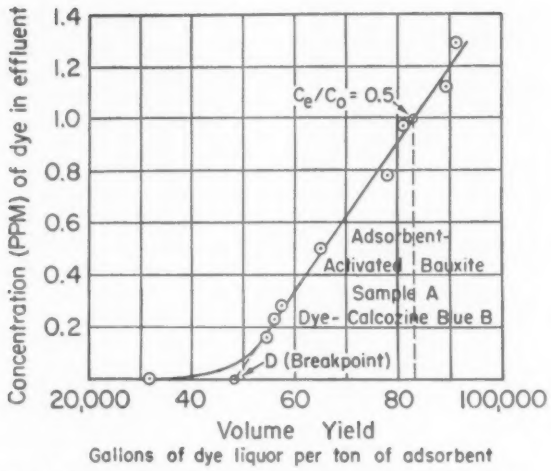

FIGURE 2.—Concentration of dye in effluent *vs.* volume yield.

data is represented graphically in Figure 4.

Some dyes were adsorbed with relatively high efficiency; others, with poor efficiency. The variation in results obtained may be due to inherent properties of the dye or adsorbent, but other factors not investigated, such as pH and temperature, also may have an influence on the results.

TABLE I.—Physical and Chemical Characteristics of Activated Bauxite and Fuller's Earth

Determination	Activated Bauxite[1]		Fuller's Earth[2]
	Sample A	Sample B	
Bulk density (lb./cu. ft.)	60.0	58.0	32.0
Surface area (sq. m./g.)	215	170	120
Tyler mesh (% by weight):			
+16	0.7	0.5	0.5
16/20	6.2	4.2	0.1
20/35	54.3	54.6	51.2
35/60	34.7	34.7	42.3
60/80	2.8	4.3	5.3
T/80	1.3	1.7	0.6
Volatile material[3] (% by weight)	9.0	4.6	3.0
Chemical analysis[4] (% by weight):			
SiO_2	10.5	13.4	66.0
MgO	—	—	10.2
Fe_2O_3	2.6	2.6	3.8
TiO_2	5.3	4.7	—
CaO	—	—	3.4
Al_2O_3 (by difference)	81.6	79.3	12.5
Undetermined[5]	—	—	4.1
Activation temp. (° F.)	750	1,100	900

[1] Porocel, furnished by Porocel Corp., Philadelphia, Pa.

[2] Attapulgus clay, furnished by Attapulgus Clay Co., Philadelphia, Pa.

[3] At 1,800° F.

[4] Volatile-free basis.

[5] TiO_2, K_2O, etc.

Space velocity has a very pronounced effect on the quantity of dye adsorbed, best results being obtained at low space velocities. This is thought to be caused by variations in the rate of diffusion of the dye liquor into the granular adsorbent. Activated bauxite does not break down in water and is in general a better adsorbent than fuller's earth for dyes. However, fuller's earth shows a high capacity for adsorption of some dyes, breaks down only slightly in water, and, in view of its low cost, shows considerable promise as an adsorbent in waste water treatment.

Initial dye concentration also has a very marked effect on the quantity of dye adsorbed, best results being obtained with high initial dye concentrations. The curves in Figure 4 represent the variation of the quantity of dye adsorbed with initial concentration of dye. It can be concluded that more

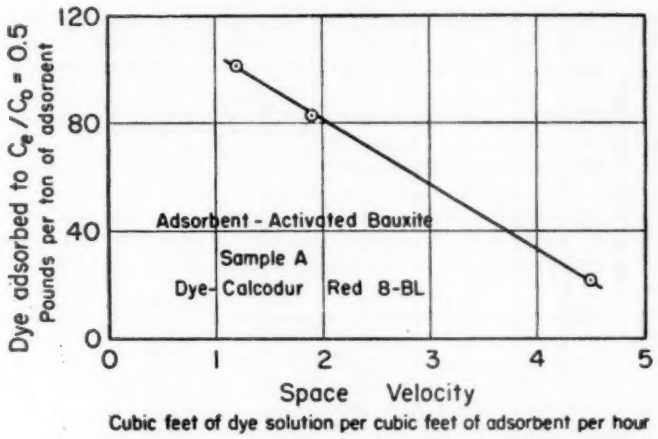

FIGURE 3.—Dye adsorbed to $C_e/C_0 = 0.5$ *vs.* space velocity.

TABLE II.—Dye Adsorbing Capacity

Adsorbent		Dye		Space Velocity[1] (vol./vol./hr.)	Dye Adsorbed to Break Point		Dye Adsorbed to $C_e/C_0 = 0.5$	
Type	Sample	Liquor	Type		(lb.)[2]	(gal.)[3]	(lb.)[2]	(gal.)[3]
Bauxite	A	Calcochrome brown RV, 200 p.p.m.; glacial acetic acid, 100 p.p.m.	Palatine mordant acid	0.984	117	70,000	202	121,000
Bauxite	A	Calcodur red 8 BL, 200 p.p.m.; sodium carbonate, 100 p.p.m.	Direct tetra-azo	1.20	80.4	48,000	101.2	60,500
Bauxite	A	Calcofast wool yellow R, 200 p.p.m.; 98% sulfuric acid, 480 p.p.m.	Chrome metallized	0.80	73	43,700	92	55,000
Fuller's earth	—	Calcofast wool yellow R, 200 p.p.m.; 98% sulfuric acid, 480 p.p.m.	Chrome metallized	1.17	0	0	11.9	7,100
Bauxite	A	Calcozine blue B, 200 p.p.m.; glacial acetic acid, 600 p.p.m.	Basic	0.75	14.8	8,900	18.0	10,800
Fuller's earth	—	Calcozine blue B, 200 p.p.m.; glacial acetic acid, 600 p.p.m.	Basic	0.88	172	103,000	182	109,000
Bauxite	A	Calcocid orange Y, 200 p.p.m.; 98% sulfuric acid, 100 p.p.m.	Acid mordant	0.92	5.8	3,500	336	200,000
Bauxite	A	Calcocid orange Y, 20 p.p.m.; 98% sulfuric acid, 100 p.p.m.	Acid mordant	0.94	2.4	14,300	—[4]	—[4]
Bauxite	A	Calcomine black, 200 p.p.m.; sodium carbonate, 400 p.p.m.; sodium chloride, 100 p.p.m.	Direct	0.76	1.0	Very small	1.6	Very small
Bauxite	A	Calcocid green S, 200 p.p.m.; 98% sulfuric acid, 100 p.p.m.	Acid mordant	0.99	0.8	Very small	1.8	Very small

[1] Volume per volume per hour.
[2] Pounds of dye per ton of adsorbent.
[3] Gallons of dye liquor per ton of adsorbent.
[4] Not obtained, as it was estimated to require 9 months continuous percolation.

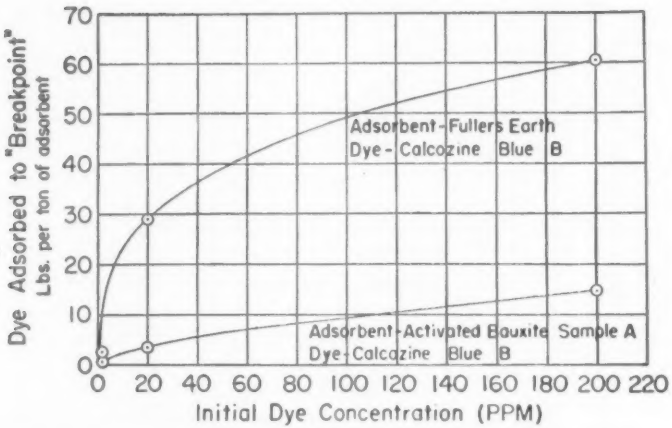

FIGURE 4.—Dye adsorbed to break point *vs.* initial dye concentration.

efficient utilization of adsorbent will be realized if dye wastes are adsorbent-treated prior to dilution by other waste water effluent from a plant.

Adsorbent Regeneration and Dye Recovery

To make adsorbent treatment of aqueous dye wastes economical, it is necessary to regenerate and re-use the adsorbent after it has become saturated with dye. This may be accomplished in the case of refractory adsorbents (such as fuller's earth and bauxite) by burning off the adsorbed dye at temperatures up to 1,100° F. Complete removal of carbonaceous material was accomplished in these experiments by heating spent adsorbent in an externally gas-fired rotary kiln at 1,000° F. for 30 min. An oxidizing atmosphere was maintained by passing a small volume of air through the kiln.

Further economy in the dye adsorption process would result if a portion of the adsorbed dye could be recovered. Three regeneration procedures directed toward this end, using dye leaching solutions, were investigated. The first procedure consisted of percolating a 50 per cent solution of acetone in water through the spent adsorbent at room temperature until the effluent showed only traces of dye. The acetone solu-

TABLE III.—Effect of Space Velocity on Quantity of Dye Adsorbed on Bauxite, Sample A

Type Dye Liquor	Space Velocity[1]	Initial Dye Concentration (p.p.m.)	Dye Adsorbed (lb./ton adsorbent)	
			To Break Point	To $C_e/C_0 = 0.5$
Calcodur red 8 BL	1.2	200	80.4	101.2
	1.9	200	28.0	82.6
	4.5	200	12.5	21.6
Calcozine blue B	0.40	200	16.2	—
	0.75	200	14.8	—
	2.00	200	5.0	—

[1] Volume per volume per hour.

TABLE IV.—Effect of Dye Concentration (Space Velocity, 1.0 Vol./Vol./Hr.)

Type Dye Liquor	Initial Dye Concentration (p.p.m.)	Dye Adsorbed to Break Point (lb.)[1]	Dye Adsorbed to $C_x/C_s = 0.5$ (lb.)[1]
(a) Activated Bauxite, Sample A			
Calcozine blue B	2.0	0.64	1.40
	20.0	3.36	5.64
	200.0	14.70	18.00
(b) Fuller's Earth			
Calcozine blue B	2.0	2.53	—
	20.0	29.00	—
	200.0	60.40	—

[1] Pounds per ton of adsorbent.

tion was passed in the same direction as the preceding dye solution. Following this, the adsorbent column was flushed with a small volume of water to displace the acetone solution and was then ready for the next cycle of dye adsorption. The second procedure consisted of percolating through the spent adsorbent a 6 per cent solution of tri-sodium phosphate in water at 200° F., followed by a hydrochloric acid-water solution at room temperature containing 150 p.p.m. hydrochloric acid. As in the first procedure, a final water flush was used to remove acid and phosphate. The third procedure consisted of percolating through the spent adsorbent at room temperature a solution composed of 12.5 per cent hydrochloric acid, 75 per cent acetone, and 12.5 per cent water. The regeneration procedure was otherwise the same as described in the two previous procedures.

The three types of wash liquors were treated as follows for recovery of dye. Recovery from the 50 per cent acetone solution was accomplished by distilling off the acetone and adding sodium chloride to salt-out or precipitate the dye, which was then recovered by filtration.

The 6 per cent tri-sodium phosphate solution was treated with sodium chloride to salt-out the dye, which was recovered by filtration.

The hydrochloric acid-acetone-water mixture was neutralized by adding tri-sodium phosphate and the solution was distilled to remove acetone. The residue was dissolved in water and salt added to precipitate the dye, which was then separated by filtration.

The decolorizing efficiency of bauxite

TABLE V.—Regenerated Adsorbent Efficiency and Dye Recovery[1]

Type Dye Liquor	Method of Regeneration	Efficiency in Sixth Cycle[2]	Recovery of Adsorbed Dye in Sixth Cycle (%)
Calcodur red 8 BL	Burning at 1,000° F.	95	0
Calcodur red 8 BL	Washing with hydrochloric acid, 12.5%; acetone, 75%; water, 12.5%	156	56
Calcocid orange Y	Burning at 1,000° F.	89	0
Calcocid orange Y	Washing with hot 6% tri-sodium phosphate followed by water acidified to a concentration of 150 p.p.m. with hydrochloric acid	68.5	92
Calcozine blue B	Burning at 1,000° F.	100	0
Calcozine blue B	Washing with acetone 50% and water 50%	64	99
Calcofast wool yellow R	Burning at 1,000° F.	0	0

[1] Adsorbent, bauxite, sample B; dye concentration, 200 p.p.m.; space velocity, 2 volumes per volume per hour.

[2] As per cent of first cycle.

(sample B) after six cycles of dye adsorption and regeneration, together with dye recovery data, is given in Table V.

In regeneration by burning, the efficiency of the adsorbent after six cycles shows only a slight loss, except in the case of Calcofast wool yellow R, a chrome dye. Adsorbents probably cannot be successfully regenerated by burning in the case of dyes leaving non-volatile inorganic residues.

Regeneration by solvent washing with dye recovery appears feasible based on the tests carried out. Suitable leaching solutions can no doubt be found for desorbing other dyes, making dye recovery possible.

Summary

Adsorbent treatment of waste water with fuller's earth and activated bauxite for the removal of dyes from waste water, to prevent stream pollution, has been investigated in the laboratory. The adsorption characteristics for a number of typical dyes in aqueous solution have been determined. Economical adsorption of dyes would require the regeneration and re-use of the adsorbent. For dyes containing no metallic constituents, successful regeneration by burning has been shown to be practical. As a possible further economy the regeneration of the adsorbents by means of solvents or salt solutions, with subsequent recovery of dye, has been found feasible for some of the dyes investigated.

The encouraging results obtained in this laboratory investigation indicate that further study of dye and similar waste treatment using inexpensive adsorbents is justified.

Acknowledgment

The authors wish to thank Dr. Peiker and F. Sundstrom and the Calco Division of the American Cyanamid Company for their valuable assistance in supplying information and materials for this study.

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EJC TASK COMMITTEE CONTACT MEMBER

In listing the members of Task Committee No. 1, Water Policy Panel, Engineers Joint Council (THIS JOURNAL, **23**, 2, 210; Feb., 1951), the name of L. H. Enslow, contact member of the committee, was inadvertently omitted.

B.O.D. DETERMINATION OF TRADE WASTE SAMPLES IN ADMIXTURE WITH SEWAGE

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A trade waste sample containing organic matter may register a low dissolved oxygen absorption because the composition of the dilution lies outside the range in which the responsible organisms can work actively. Additions, such as nitrogen and phosphates, to the diluting water have been suggested to overcome the difficulty (1). It has become customary in the Nottingham sewage laboratory to add settled sewage as the best means both of insuring the presence of all the essential nutrients and of supplying a large seeding of the necessary organisms themselves. The dissolved oxygen absorption of the sewage sample used is determined separately, thereby enabling the calculation of a value for its share of the absorption in the mixture. This is subtracted from the recorded absorption of the mixture and the resulting balance is debited to the waste. The assumption is made that the settled sewage registers the same absorption whether alone or in admixture.

Procedure

Let A be the suitably diluted trade waste sample and B the suitably diluted settled sewage. Then suppose x parts of A are mixed with y parts of B and the mixture absorbs q parts of oxygen. Finally, let p parts be the dissolved oxygen loss of B. The absorption due to the waste sample in the mixture on these assumptions is

$$\text{Absorption} = q - p\left(\frac{y}{x+y}\right) \quad (1)$$

In terms of the dilution A, itself, the absorption is

$$\text{Absorption} = \frac{x+y}{x}\left\{q - p\left(\frac{y}{x+y}\right)\right\} \quad (2)$$

It is merely necessary to multiply the resulting value by the degree of dilution of A to get the B.O.D. of the trade waste sample when supplied with the nutrients it would possess if mixed with that proportion of sewage.

Calculation is easiest when equal volumes of the waste and sewage dilutions are used in the mixture. In this case, Eq. 2 reduces to

$$\text{Absorption} = (2q - \tfrac{1}{2}p)$$

When a number of mixtures of A and B are made, the calculated absorption sometimes increases as the sewage-waste ratio increases.

Experimental Results

Dilutions of various wastes and settled sewage were made and incubated separately and when mixed in various proportions. The waste was, of course, neutralized and seeded before starting.

It was anticipated that the samples of waste would fall into three groups according as to whether the absorption of the mixture was greater than, equal to, or less than that calculated from the separate incubation of the constituents. This might possibly serve as a threefold primary classification of trade waste samples. The facts were rather different. No cases occurred where the actual absorption was less than calculated. Several cases were found where it was more. In the majority, the calculated and experimental values of the

mixture were approximately the same.

Gas liquor was an outstanding example of increased absorption in admixture. It was necessary in this case to use the azide method of determining dissolved oxygen. The first sample submitted to the suggested procedure gave the results recorded in Table I. Obviously, the gas liquor absorbed much more in admixture than either constituent. By the use of Eq. 3 the absorption in the mixture was 4,970 p.p.m., as against 1,460 p.p.m. when incubated alone. Later experiments gave similar results. In the case cited in Table II, the time of incubation was reduced to allow the use of stronger dilutions. Once again the absorptions of the mixes are all greater than the absorption of either constituent. The absorptions calculated as p.p.m. of the gas liquor sample are given in Table III. They are calculated in the usual way when incubated alone, and by Eq. 2 in the case of mixtures. The ratio of settled sewage to waste in the incubated bottle is given in Col. 1.

TABLE I

	Dissolved Oxygen Loss in 5 Days at 65° F. (p.p.m.)
Gas Liquor Dilution	2.92
Settled Sewage Dilution	6.81
1:1 Mixture	8.37

TABLE II

	Dissolved Oxygen Loss on Incubation at 65° F. (p.p.m.)	
	2-Day	3-Day
Gas Liquor 1/600 dil.(A)	1.39	1.85
Gas Liquor 1/1,200 dil.	1.33	1.59
Settled Sewage 1/40 dil.	2.93	3.80 (B)
3A:1B Mix.	5.37	6.71
1A:1B Mix.	5.67	6.96
1A:2B Mix.	5.09	6.17

The B.O.D. of the gas liquor is obviously dependent to some extent on the degree of dilution. It is equally apparent that the calculated B.O.D. of the gas liquor in various mixtures tends to an upper limit of about 6,500 p.p.m. in three days.

TABLE III

Ratio Settled Sewage / Gas Liquor	Dissolved Oxygen Absorption (p.p.m.) of Gas Liquor Incubated for	
	2 Days	3 Days
Nil (1/600)	834	1110
Nil (1/1,200)	1596	1908
5	3728	4608
15	5040	6072
30	5634	6534

B.O.D. of Mixtures of Trade Wastes

The organisms causing the loss of dissolved oxygen in the B.O.D. test require certain nutrients. A mixture of wastes from two industries is, therefore, more likely to be within the necessary range than either waste alone. A gas liquor and the neutralized effluent from a plant making sulfa drugs were each seeded with sewage and incubated after suitable dilution alone and in admixture. Table IV shows that the absorption of the mixture was greater than either constituent.

Alternative Variations in Suggested Procedure

A trade waste is usually mixed with domestic sewage and other trade wastes in the sewers. It is, therefore, the effect it will exert on the analysis of the mixture that is of most concern. The maximum B.O.D. recorded in admix-

TABLE IV

	Loss of Dissolved Oxygen in 5 Days at 65° F. (p.p.m.)
Gas Liquor Dilution	6.26
Organic Chemical Waste	3.28
1:1 Mixture of Above	6.61

ture with sewage is the most probable measure of the load imposed on the river or purification device by the presence of the waste in the sewage.

Other analysts, fearing that the presence of the waste may in fact stimulate the absorption of the sewage in the mixture, may not feel disposed to use such large proportions of settled sewage in the mixture. It is indeed true that in most of the cases investigated the waste would exert approximately its maximum demand when one volume of sewage dilution is mixed with three volumes of the suitably diluted waste. Using the previously defined symbols, the absorption due to the waste at dilution A would be

$$\text{Absorption} = \tfrac{4}{3}(q - \tfrac{1}{4}p)$$

Mixture of the sewage and waste may be done before dilution, but the calculations are more difficult.

Discussion

The Royal Sewage Commission was aware of the necessity of insuring that B.O.D. results were additive in admixture (2). The suggested procedure would insure this so far as sewage is concerned.

It must not be forgotten that unusual results may arise from the interference of some compound in the waste with the method of determining dissolved oxygen. For example, it was impossible to determine the dissolved oxygen of dilutions of the gas liquor used by the Rideal-Stewart method.

Plating wastes and purely inorganic wastes were not considered.

Acknowledgment

Thanks are due to the Sewage Disposal Committee of the Nottingham Corporation for permission to publish this communication.

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A SALINIMETER FOR DENSITY CURRENTS

A meter for recording the salt concentration at different depths in a body of water has been designed by G. H. Keulegan of the National Bureau of Standards. The instrument is equally effective in still or flowing water. Although the salinimeter was built originally for laboratory use, it may be adapted easily to observations in rivers and other navigation channels.

A typical problem for the salinimeter would be the measurement of salt water intrusion from the Atlantic Ocean into Chesapeake Bay, or from the Bay into one of the tributary rivers. The dispersion of salt in an internal navigation channel behind a lock can also be measured with the instrument.

In wastes treatment the device would have application in studying diffusion and movement of sewage discharged into sea water, as well as in sedimentation tank studies and other research in plant hydraulics.

Stream Pollution

SURVEY OF INDUSTRIAL WASTES IN THE LAKE HURON—LAKE ERIE SECTION OF THE INTERNATIONAL BOUNDARY WATERS*

Part I. Introduction and Canadian Section

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The vast waterway system marking the boundary between the United States and Canada is vital to both countries. The manifold uses which these waters now serve make it imperative that nothing shall jeopardize this unequalled international asset. These waters are utilized, among other things, for domestic and industrial water supplies, sanitary purposes, shipping and commerce, recreation, power, and drainage. This discussion is concerned primarily with those factors which may influence the sanitary quality of the waters or may adversely affect recreation and wild life.

The Boundary Waters Treaty

The significance of pollution in these boundary waters is revealed in a treaty, signed in 1909, between the United States and Great Britain. This treaty stipulated, in Article IV, that boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other side. Provision is also made, in Article VII, for establishing and maintaining an International Joint Commission of six members. Provision is made for submitting to the Commission any problem involving the rights or interests of either country along the common frontier. This procedure involves an inquiry and report to the Governments of the respective countries. The valuable work of the Commission all through the intervening years has been recognized throughout the world as an admirable method for settling the numerous problems which must be expected on such a lengthy border.

The Previous Investigation

Pollution of the boundary waters has been a continuing problem for many years. It resulted in a reference from the two Governments to the International Joint Commission and an investigation in 1913. At that time the entire boundary waters were studied. The report of the Commission was later presented to the two countries. It contained recommendations for remedial measures, but the outbreak of World War I and later events adversely affected action on these changes.

No further investigation was undertaken by the International Joint Commission until 1946. At this later time the extent of the boundary to be studied was reduced, but the scope and intensity of the investigation was widened. This was the result of the changes which had taken place in the 33 years between examinations of these waters.

* Presented at 23rd Annual Meeting, Federation of Sewage and Industrial Wastes Assns.; Washington, D. C.; October 9–12, 1950.

Terms of Reference in 1946

Representation had been made to the two Governments on pollution carried by the boundary waters. Accordingly and taking advantage of the provisions of the treaty, a reference was made on April 1, 1946, to the International Joint Commission. The terms of the reference are as follows:

"I have the honor to inform you that the Governments of the United States and Canada have been informed that the waters of the St. Clair River, Lake St. Clair, and the Detroit River are being polluted by sewage and industrial wastes emptied into those waters. Having in mind the provisions of Article IV of the Boundary Waters Treaty signed January 11, 1909, that boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health or property on the other side, the two Governments have agreed upon a joint Reference of the matter to the International Joint Commission, pursuant to the provisions of Article IX of said Treaty. The Commission is requested to inquire into and report to the two Governments upon the following questions:

"(1) Are the waters referred to in the preceding paragraph, or any of them, actually being polluted on either side of the boundary to the injury of health or property on the other side of the boundary?

"(2) If the foregoing question is answered in the affirmative, to what extent, by what causes, and in what localities is such pollution taking place?

"(3) If the Commission should find that pollution of the character just referred to is taking place, what measures for remedying the situation would, in its judgment, be most practicable from the economic, sanitary and other points of view?

"(4) If the Commission should find that the construction or maintenance of remedial or preventive works is necessary to render the waters sanitary and suitable for domestic and other uses, it should indicate the nature, location and extent of such works, and the probable cost thereof, and by whom and in what proportions such cost should be borne.

"For the purpose of assisting the Commission in making the investigation and recommendations provided for in this Reference, the two Governments will, upon request, make available to the Commission the services of engineers and other specially qualified personnel of their governmental agencies, and such information and technical data as may have been acquired by such agencies, or as may be acquired by them during the course of the investigation.

"The Commission should submit its report and recommendations to the two Governments as soon as practicable."

It will thus be seen that the Commission was asked to study all phases of pollution which might affect the other side of the boundary, and to report to the two Governments on remedial measures and the costs involved.

This term of reference was extended later on two occasions to include, first, the St. Marys River, and secondly, the Niagara River. This paper, however, deals only with the waters of the St. Clair River, Lake St. Clair, and the Detroit River (see Figure 1).

Board of Technical Advisers

One of the first steps of the Commission, in meeting the terms of reference, was the appointment of a Board of Technical Advisers. This action was taken on May 15, 1946, when a Board of eight engineers was selected. Four of these were from the United States and four from Canada. The selection included two from the federal service of each country, and two from the state or provincial service bordering on the waters in question. The members of the Board were as follows:

For the United States: J. K. Hoskins (later succeeded by L. M. Fisher) and M. LeBosquet, Jr., all of whom were in the United States Public Health Service.

For Canada: G. H. Ferguson, and W. R. Edmonds, both of the Department

of National Health and Welfare. On the retirement of Mr. Ferguson his place was taken by R. J. Menzies.

For the State of Michigan: J. M. Hepler of the Michigan Department of Health, and L. F. Oeming of the Michigan Water Resources Commission.

For Ontario: A. E. Berry, and A. V. DeLaporte of the Ontario Department of Health.

The Board was given wide authority in the conduct of the investigation. It was asked to carry out the necessary field work and to advise the Commission on the questions contained in the terms of reference. The Board had unrestricted freedom in the procedure to be followed, and it had access to data from many sources.

Organization for the Investigation

This investigation required a large amount of field work. The personnel for this was supplied by the United States Public Health Service, the Department of National Health and Welfare of Canada, the Michigan Stream Control Commission, and the Ontario Department of Health. The Board organized the field work and distributed it between the United States and Canadian field staffs. Field laboratories were established at convenient locations, and these were supplemented by the permanent laboratories of the participating groups.

The selection of sampling points for this investigation was influenced by such factors as the location of known pollution sources, the characteristics of the stream flows, and the location of points used during the 1913 survey. The known pollution sources included municipal and industrial sewer outlets found along the shores of these waters and tributaries. Stream flow characteristics were considered significant in that they influence the dispersion of pollution throughout these boundary waters. Comparison of results with those of the 1913 survey was desired, and many of the sampling points used in the 1946–1948 investigation were the same.

For the purpose of identifying the location of sampling ranges, sewer outlets and other important points on the rivers and their tributaries, a mileage index system was used for the present investigation. This system involves the use of one or more letters to identify the stream or streams, followed by a number which represents the distance in river miles from the mouth or other point of reference. The reference points correspond to the zero mileage points established by the United States Corps of Engineers.

Laboratory Determinations

In the early stages of this investigation all recognized tests for measuring domestic and industrial pollution were made on a routine basis. Routine determinations included coliforms, chlorides, phenols, ammonia, chlorine demand, dissolved oxygen, biochemical oxygen demand, hydrogen ion concentration (pH), turbidity, and alkalinity. Tests for oils, cyanides, solids, tastes, and odors were made periodically. After it was found that certain of the routine tests would be of limited value in disclosing the nature or extent of the pollution, they were discontinued. This resulted, for example, in the elimination of the pH, alkalinity, and chloride tests at certain locations.

In general, analytical procedures followed were those contained in "Standard Methods For The Examination of Water and Sewage," 8th and 9th Editions (1936 and 1946). Specific techniques were developed where an accepted method was not available, where the standard test for a specific compound was not sensitive enough for the high dilutions encountered, or where other substances caused interference. Such special procedures included those for oils, phenols, cyanides, and tastes.

Possible variations in techniques between the laboratories of the two field

staffs were recognized and guarded against in many ways. Specific batches of laboratory media were set aside for this investigation and all tests conducted in either laboratory were made with the same media. Sampling assign-

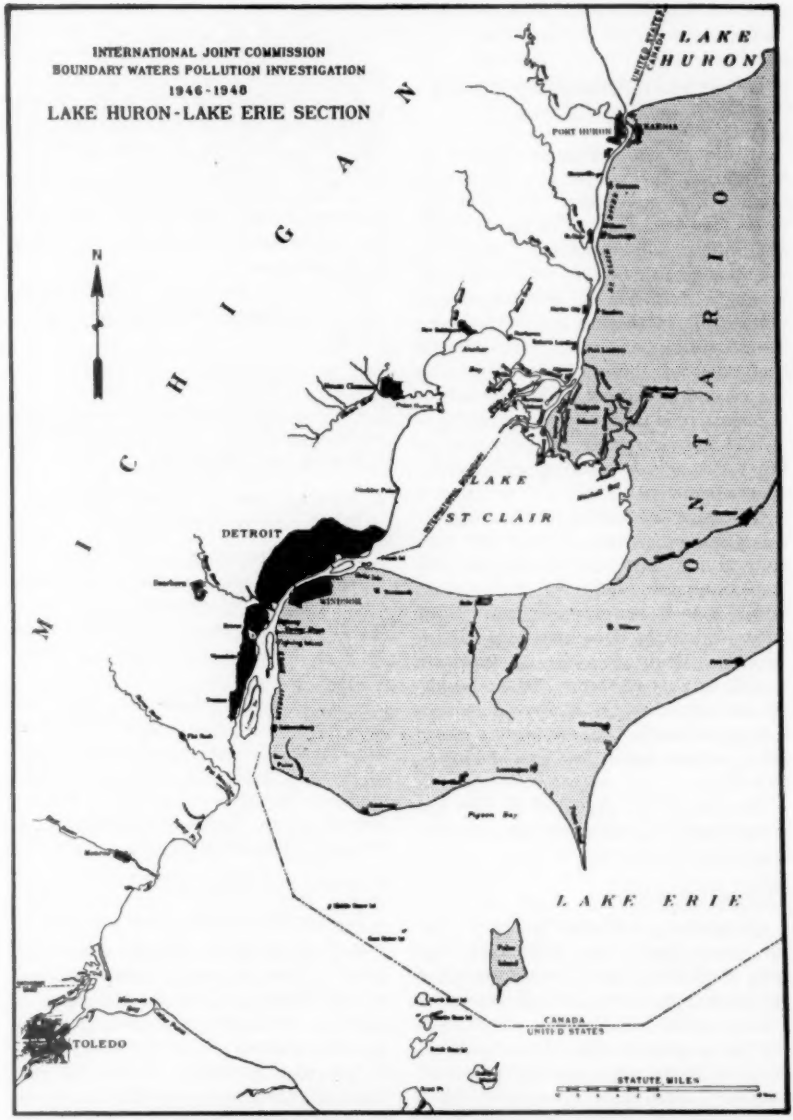

FIGURE 1.—General area of 1946–48 International Boundary Waters pollution investigation in Lake Huron-Lake Erie section.

ments were interchanged from time to time in order that any variations in techniques would tend to be minimized. Checks on analytical procedures were made by dividing samples between laboratories.

Objectives for Boundary Waters Quality Control

It was recognized early in this investigation that objectives for water quality were necessary. The formulation of such objectives is essential for defining remedial measures. Objectives may be established in two ways: 1) through limitation of the quantity of deleterious substances allowed to enter the receiving streams, or 2) through limitation of these substances within the receiving waters. Whichever type of objective is used, the end result must be the same; namely, maintenance of the water in a condition suitable for all subsequent uses.

Objectives adopted for boundary waters quality control establish the ultimate aim of corrective measures. Objectives must be defined if stream sanitation is to be accomplished, and they must be impartial in setting goals for all uses. Each purpose will require a specific quality of water. In the majority of cases, the uses of any one watercourse are varied, and complex interrelationships must be considered in objectives consistent with all uses.

The objectives prepared by the two Boards and endorsed by the Commission are as follows:

General Objectives

All wastes, including sanitary sewage, storm water, and industrial effluents, shall be in such condition when discharged into any stream that they will not create conditions in the boundary waters which will adversely affect the use of these waters for the following purposes: source of domestic water supply or industrial water supply, navigation, fish and wild life, bathing, recreation, agriculture, and other riparian activities.

In general, adverse conditions are caused by:

1. Excessive bacterial, physical, or chemical contamination.
2. Unnatural deposits in the stream, interfering with navigation, fish and wild life, bathing, recreation, or destruction of aesthetic values.
3. Toxic substances and materials imparting objectionable tastes and odors to waters used for domestic or industrial purposes.
4. Floating materials, including oils, grease, garbage, sewage solids, or other refuse.

Specific Objectives

In more specific terms, adequate controls of pollution will necessitate the following objectives for:

A. Sanitary Sewage, Storm Water, and Wastes from Water Craft

Sufficient treatment for adequate removal or reduction of solids, bacteria, and chemical constituents, which may interfere unreasonably with the use of these waters for the purposes aforementioned.

Adequate protection for these waters, except in certain specific instances influenced by local conditions, should be provided if the coliform M.P.N. median value does not exceed 2,400 per 100 ml. at any point in the waters following initial dilution.

B. Industrial Wastes

1. Chemical wastes, phenolic type.

Industrial waste effluents from phenolic hydrocarbon and other chemical plants will cause objectionable tastes or odors in drinking or industrial water supplies and may taint the flesh of fish.

Adequate protection should be provided for these waters if the concentration of phenol or phenolic equivalents

does not exceed an average of 2 p.p.b. and a maximum of 5 p.p.b. at any point in these waters following initial dilution. This quality in the receiving waters will probably be attained if plant effluents are limited to 20 p.p.b. of phenol or phenolic equivalents.

Some of the industries producing phenolic wastes are: coke, synthetic resin, oil refining, petroleum cracking, tar, road oil, creosoting, wood distillation, and dye manufacturing plants.

2. Chemical wastes, other than phenolic.

Adequate protection should be provided if:

(a) The pH of these waters following initial dilution is not less than 6.7 nor more than 8.5. This quality in the receiving waters will probably be attained if plant effluents are adjusted to a pH value within the range of 5.5 and 10.6.

(b) The iron content of these waters following initial dilution does not exceed 0.3 p.p.m. This quality in the receiving waters will probably be attained if plant effluents are limited to 17 p.p.m. of iron in terms of Fe.

(c) The odor-producing substances in the effluent are reduced to a point that following initial dilution with these waters the mixture does not have a threshold odor number in excess of 8 due to such added material.

(d) Unnatural color and turbidity of the wastes are reduced to a point that these waters will not be offensive in appearance or otherwise unattractive for the aforementioned uses.

(e) Oil and floating solids are reduced to a point such that they will not create fire hazards, coat hulls of water craft, injure fish or wild life or their habitat, or will adversely affect public or private recreational development or other legitimate shore line developments or uses. Protection should be provided for these waters if plant effluents or stormwater discharges from premises do not contain oils, as determined by extraction, in excess of 15 p.p.m. or a sufficient amount to create more than a faint irridescence.

Some of the industries producing chemical wastes other than phenolic are: oil wells and petroleum refineries, gasoline filling stations and bulk stations, styrene copolymer, synthetic pharmaceutical, synthetic fibre, iron and steel, alkali chemical, rubber fabricating, dye manufacturing, and acid manufacturing plants.

3. Highly toxic wastes.

Adequate protection should be provided for these waters if substances highly toxic to human, fish, aquatic, or wild life are eliminated or reduced to safe limits.

Some of the industries producing highly toxic wastes are: metal plating and finishing plants discharging cyanides, chromium, or other toxic wastes; chemical and pharmaceutical plants; and coke ovens. Wastes containing toxic concentrations of free halogens are included in this category.

4. Deoxygenating wastes.

Adequate protection of these waters should result if sufficient treatment is provided for the substantial removal of solids, bacteria, chemical constituents, and other substances capable of reducing the dissolved oxygen content of these waters unreasonably. Some of the industries producing these wastes are: tanneries; glue and gelatin plants; alcohol, including breweries and distilleries; wool scouring; pulp and paper; food processing plants, such as meat packing and dairy plants; corn prod-

ucts; beet sugar; fish processing; and dehydration plants.

[Note: The methods of determination of the chemical constituents referred to in the preceding objectives are as given in "Analytical Methods For Boundary Waters Quality Control" as prepared by the Board of Technical Advisers. Bacterial determinations are to include the presumptive and confirmed tests for the coliform group of bacteria as given in "Standard Methods for the Examination of Water and Sewage" 9th Edition (1946).]

Hearings Before the Commission

Public hearings for municipalities, industries, and all other interested parties were held by the Commission at the conclusion of the field studies. The purpose of these was to obtain information on waste treatment processes in use or proposed, cost estimates for remedial measures, time required to carry out these measures, and comments on the application of the objective to specific wastes. Much useful information was made available by this procedure.

BASIC CONSIDERATIONS

The Great Lakes Waterway

The boundary waters between the United States and Canada comprise the largest body of fresh water in the world. Large populations and great industries have developed along the shores of these watercourses, attracted by the available facilities so essential for domestic and industrial water supplies, recreation, drainage outlets, and for transportation and power. Ready access to natural resources, combined with low-cost water transportation, has offered in the last 25 years of this industrial age every inducement to rapid expansion of the area both commercially and residentially. These facilities are equally appealing for developments in the future. Thus, the potentialities of the Great Lakes waterway are difficult to conjecture except in superlative terms.

Uses of Boundary Waters

Any investigation of this problem is at once confronted with the uses to which these waters are applied. The importance of boundary water pollution arises both from the multiplicity of purposes for which these waters are utilized and the resulting conflict between these uses. Article VIII of the treaty between the United States and Great Britain relating to boundary waters, signed January 11, 1909, states:

"The following order of precedence shall be observed among the various uses enumerated herein-after for these waters, and no use shall be permitted which tends materially to conflict with or restrain any other use which is given preference over it in this order of precedence:

1. Uses for domestic and sanitary purposes;

2. Uses for navigation, including the service of canals for the purposes of navigation;

3. Uses for power and for irrigation purposes."

This order of precedence is highly significant in that domestic and sanitary purposes, which are so closely related to public health, are given priority over all other uses. It is also significant that other water needs, such as for industry, for recreation, and for the support of fish and wild life, which have come into prominence in the intervening years, are not specifically cited in the treaty. It is recognized that these waters have now come to serve this expanded category of uses. Irrespective of the uses made, the treaty requires that these boundary waters shall not be polluted on either side to the injury of health or property on the other.

These waters constitute a natural resource which has been developed to a high degree by both countries. The connecting waters from Lake Huron to

Lake Erie are used as a source of domestic water supply by nearly 3,000,000 people, residing in some 50 communities. They also receive the domestic wastes from approximately 2,500,000 people. In one season of navigation nearly 3,000,000 persons were carried in vessels, the wastes from which entered the waters. The St. Marys River is a source of water supply for the two cities of Sault Ste. Marie and receives all the sewage as well. In the Niagara River area about 1,000,000 persons residing in some 40 communities use the river as a source of domestic water supply.

Similarly, the water used for industrial purposes and pumped from these sources amounted to 1,400 m.g.d. (U.S.), in the Lake Huron-Lake Erie section, 98 m.g.d. (U. S.) in the St. Marys River area, and 500 m.g.d. (U. S.) from the Niagara River, making a total of nearly 2,000 m.g.d. (U. S.) exclusive of what is secured by industry through municipal waterworks systems.

Hydrometric Data

Hydrometric data on a watercourse can be used to evaluate the effects of flow, currents, distribution into channels, and other related factors which influence stream pollution. In the Lake Huron-Lake Erie section large volumes of water, strong and variable currents, and numerous channels transport and dilute the incoming waste discharges. Pollutants which are highly concentrated at the point of discharge may become greatly diluted in certain areas and may remain concentrated in others. Even these dilute quantities may be carried long distances and cause objectionable conditions in the boundary waters. Pollution is important at its immediate point of discharge. The degree of its subsequent importance will be influenced by the time of flow, volume, intermingling, and other stream characteristics.

A detailed knowledge of river and lake currents is essential in determining transboundary travel of polluted waters.

The flow in the St. Clair River during the 48-year period from 1900 to 1947 has averaged 174,000 c.f.s. The river has a mean velocity of about 5 m.p.h. near its upper end in the vicinity of the Blue Water Bridge. In the lower reaches, through the South Channel, the velocity is about 2 m.p.h. At intermediate points the velocity varies irregularly between these limits.

The St. Clair River enters Lake St. Clair through six channels. Approximately 87.5 per cent of the flow enters the northwestern section of Lake St. Clair through the North, Middle, and South Channels. Only 12.5 per cent enters the much larger portion of the lake on the Canadian side through three smaller channels.

The flow in Lake St. Clair is augmented by an inflow of about 2,300 c.f.s. from tributaries other than the St. Clair River. The lake holds approximately 120,400,000,000 cu. ft. of water. If there were complete and uniform displacement of the lake water by the St. Clair River flow alone it would take 8 days under average conditions for the incoming water to reach the Detroit River. Observations made in two instances showed the time of passage was between 5 and 7 days.

The average flow in the Detroit River is recorded at about 177,000 c.f.s. At the head, approximately 70 per cent of the total flow passes to the United States side of the boundary through the larger channel between Windmill Point and Peach Island, and only 30 per cent passes between Peach Island and the Canadian shore. Below Peach Island the flow of the river is divided at several points by islands, and the distribution of flow is altered from side to side at these places.

Transboundary Currents

It is apparent that transboundary currents occur at various places. In

the St. Clair River, surface float studies indicated a crossing of surface waters from the Canadian side to the United States side in the area between St. Clair and Marine City. Similar floats released on the United States side were generally carried downstream and crossed to the Canadian side between Courtright and Sombra. Reports were received on 380 out of a total of 1,020 surface floats released in the St. Clair River. Of these, 32 crossed from the United States to Canada, and 97 crossed from Canada to the United States. On the other hand, a three-week study of subsurface floats submerged to depths of 2 to 20 ft. and released along both shores in the Sarnia-Port Huron area revealed that they followed a course parallel to the shores and showed no pronounced tendency to cross the International Boundary. The deeper floats, at 15 to 20 ft., released on the Canadian side near Port Lambton, traveled down the Chenal Ecarte; those submerged to depths of less than 10 ft. followed down the main or South Channel and probably across the boundary.

In Lake St. Clair both surface and depth floats crossed the boundary at different points. Movements of water were not well defined, but depended largely on wind direction and intensity. Surface floats released at the outlet of Anchor Bay crossed the boundary to Mitchell Bay and the south shore of the lake. Depth floats also followed a similar course toward the boundary. It is probable that these would cross the boundary under certain wind conditions. There was no indication of currents from the east side of Lake St. Clair crossing the boundary prior to the approach to the Detroit River.

In the Detroit River, surface floats crossed from side to side throughout the length of the stream. In the upper part these floats crossed from the United States side through the opening between Peach Island and Belle Isle to the Canadian side. Several surface floats released at the mouth of the Rouge River and in the vicinity of the Detroit sewage treatment plant outlet were found on the Canadian shore opposite the upper end of Fighting Island. Only those depth floats placed 1,000 ft. or more off the United States shore, opposite Windmill Point, crossed the boundary. A limited number of depth floats placed in United States waters near the boundary at the head of Fighting Island crossed into Canadian waters at the foot of this island.

Indications of coliform pollution crossing the boundary are seen at a number of places. In the St. Clair River there is a diffusion of coliforms at range SR-17.5,* between Sombra and Marine City, after passage through a narrow section of the river. This indicates a transboundary movement of pollution. In Lake St. Clair the coliform concentrations indicate a flow of pollution from Anchor Bay across the boundary similar to the path followed by the floats. Diffusion of coliform concentrations occur at several places in the lower Detroit River, beginning on the Canadian side at the head of Fighting Island. This may be influenced by material from across the boundary. More uniform distribution is found at range Dt-12.Ow in Trenton Channel and at range Dt-9.3e, which crosses the boundary above Amherstburg. These ranges are on either side of Grosse Ile. On range Dt-3.9, at the mouth of the Detroit River, there is a trend to uniform distribution across the entire width of the river.

Transboundary movement of pollution was demonstrated by an accidental spill of phenol in the Sarnia area. This took place on November 30 and December 1, 1948. Severe taste occurrences were reported at Wallaceburg on December 1, and at the Detroit water treatment plant on December 7 to 10. This was followed by tastes at Windsor on December 14 and 21.

* Range locations are shown on Figures 2, 3, and 4.

Availability of Natural Resources

Centralization of industry in this section of the boundary has been conspicuous. Availability of primary natural resources has contributed much to this on both sides of the boundary. Iron ore, salt deposits, petroleum, gas, and other products required for industry are readily obtained.

In this investigation 56 industries were studied—39 on the United States side and 17 on the Canadian side.

Industrial wastes are the chief source of chemical pollution, as distinguished from bacterial pollution in sewage. They are much less significant from a disease standpoint. The chief objection to many of these wastes is that they contain oils, toxic substances, or taste- and odor-producing compounds. Other polluting effects result from the discharge of solids, acids, oxygen-consuming wastes, and materials which impart an unsightly appearance.

Pollution by industrial wastes occurs throughout the Lake Hurón-Lake Erie section, but is heaviest in the upper St. Clair and lower Detroit Rivers.

CANADIAN SECTION

Industrial surveys on the Canadian side of the boundary were carried out on all major plants discharging wastes to these watercourses. These included such types as automotive, chemical, distillery, gas manufacturing, miscellaneous metals, oil, rubber, salt, and steel.

A summary of the industrial wastes discharged daily on the Canadian side showed 190 m.g.d. (Imp.), or 228 m.g.d. (U. S.). Included were the following: 200 lb. of phenol, 5 lb. of cyanides, 560 lb. of ammonium compound, 2,040 Imp. gal of oil (2,450 U. S. gal.), and 593,300 lb. of suspended solids. The B.O.D. of these wastes amounted to 114,600 lb. daily for an equivalent population of 682,000 persons.

Some of the major industries on the Canadian side are: oil refinery, synthetic rubber, gas manufacturing, automotive, chemical, salt, and miscellaneous metals. These discharge wastes into the boundary waters at various locations. Some of these have been in operation for long periods. Varying degrees of treatment of the wastes have been applied, and programs for additional remedial measures are being actively pursued. Industry has recognized the need for clean streams, and is cooperating in an effort to attain this objective.

Part II. United States Section

By H. H. Black and L. F. Oeming

Respectively, Senior Sanitary Engineer, U.S.P.H.S., Cincinnati, Ohio; and Chief Engineer, Michigan Water Resources Commission, Lansing, Mich.

This section briefly describes the industrial waste program conducted as a part of this survey, explains pertinent factors having bearing on the industrial pollutional constituents studied, summarizes the results of two special studies, indicates the progress in pollution control during the survey period, and outlines the continuing program.

Industrial Waste Program

Engineering Investigations

Thirty-nine United States industrial corporations, with plants discharging industrial wastes either directly to the International Boundary Waters or their tributaries, were visited as a part of the program for study of pollution sources. Initial conferences were

scheduled by letter through the Michigan Water Resources Commission. Separate conferences were held with officials and technical representatives of each industry. Engineers representing the Michigan Water Resources Commission and the U. S. Public Health Service participated in each meeting.

These conferences were arranged for the purpose of discussing process wastes produced by each industry and their relation to pollution of the International Boundary Waters. Basic information regarding volume and characteristics of wastes was requested. Inspection of major waste sources within the plant was made a part of these engineering investigations. Following each technical meeting with industry, a detailed memorandum was prepared by U. S. P. H. S. engineers and forwarded to the industry for review and approval before considering it official record. Frequently, the industry was requested to furnish supplemental information in order to complete the record.

Cooperative Surveys

Information obtained from the engineering investigations served as a basis for classifying the industries into two groups— those for which adequate waste data were considered available, and those on which more information was needed. There were 14 industries in the second group. The U. S. P. H. S. field staff conducted surveys at 10 of these industries and representatives of the Michigan Water Resources Commission made detailed waste studies at the remaining four plants.

These surveys were cooperative projects with the state and with industry. Each project was organized along the same lines, being modified as necessary to conform with requirements of the plant studied. The industrial representative was usually from the research department or the plant engineer's office, with knowledge of the plant and process as a prime requisite. Industry assumed responsibility for installation of flow measuring equipment, when necessary, and the collection of representative samples.

Normally the major individual wastes within the plant were studied along with the combined waste. This procedure identified the principal sources, permitted computing constituent balances, and made the results of maximum value. Samples were frequently divided between the industrial laboratory and the U. S. P. H. S. laboratory, the analytical work being duplicated. This gave the industry data from its own laboratory and provided opportunity for checking techniques. On completion of the study, the results were compared and if there was significant disagreement additional work was performed. Normally these surveys extended through five consecutive days. A report was prepared on each survey by the U. S. P. H. S. staff and forwarded to the state and to the industry.

Correlation with Receiving Waters

Stream and lake observations were designed to trace the course of pollutional materials and to determine their persistence in those natural waters. This phase of the program was particularly important because of difficulties reported, especially since the early years of World War II, by municipal water purification plant operators with tastes and odors which were attributed to industrial wastes. This work was complicated by the limitations of analytical procedures for determination of specific constituents in extremely high dilutions.

The results of these industrial pollution studies are illustrated by the stream and lake phenol results, which have been superimposed as barographs on maps of these International Boundary Waters (Figures 2, 3, and 4). Average phenol concentrations are recorded for St. Clair River and Detroit River. The maximum phenol concen-

trations, as well as the average, are shown for Lake St. Clair, the maximum at each sampling point being correlated with the prevailing wind direction at the time it occurred.

Cognizance was taken of other highly significant taste- and odor-producing compounds, known to be discharged with industrial wastes to these boundary waters, for which there were no known reliable tests in high dilutions. In the absence of specific chemical procedures, a limited amount of taste and odor work was performed both on the natural waters subject to pollution and on the concentrated industrial wastes suspected of being sources of highly persistent taste- and odor-producing compounds. The results of this work supplemented phenol data and indicated certain wastes warranting further investigation.

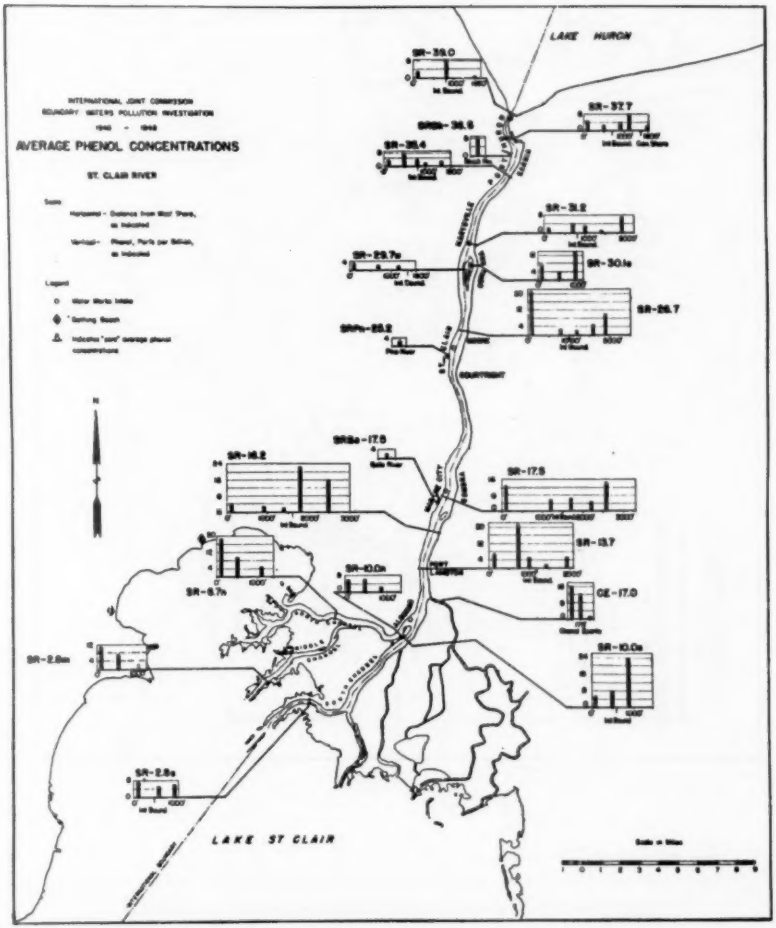

FIGURE 2.—Average phenol concentrations in St. Clair River.

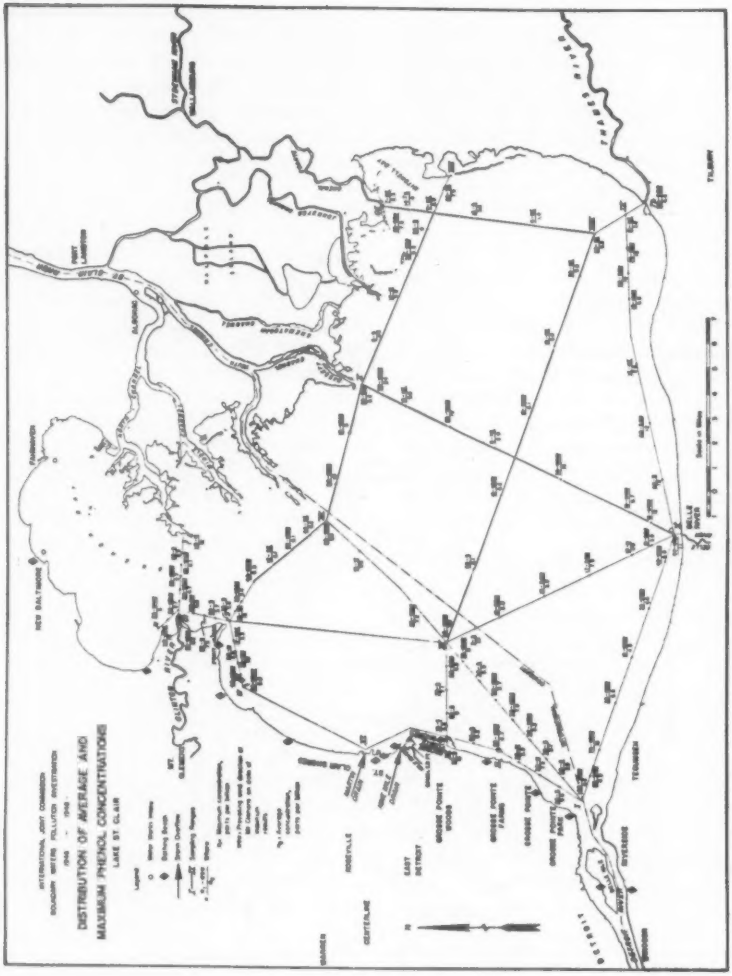

FIGURE 3.—Distribution of average and maximum phenol concentrations in Lake St. Clair.

Analytical Problems

Detailed discussion of the many analytical problems encountered during the course of this project is beyond the scope of this paper. The survey embraced essentially two types of investigations:

1. The study of industrial plant wastes or component parts thereof.
2. The analysis of the actual boundary waters.

In the analysis of plant wastes, analytical problems continuously arose from the heterogenous nature of such

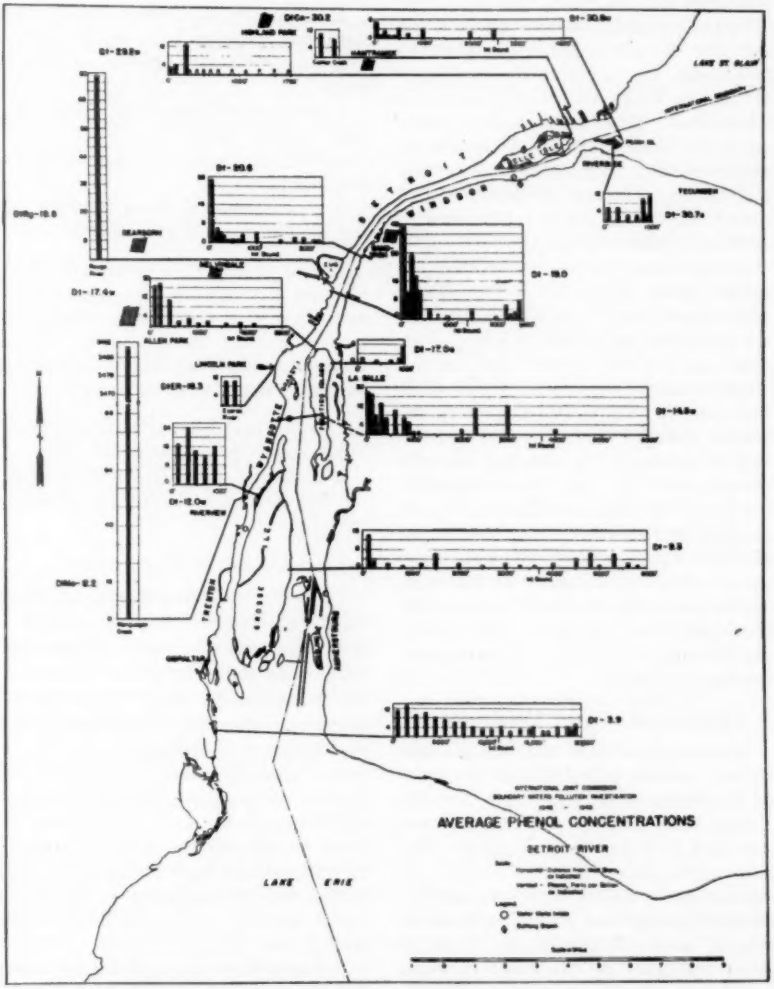

FIGURE 4.—Average phenol concentrations in Detroit River.

wastes. In seeking to measure a specific polluting component of an industrial plant effluent, there was always the problem of separating that material from the rest of the waste or devising or selecting a procedure which was not adversely affected by the other components of the waste. Such analytical problems are not easily solved.

In the examination of boundary waters, on the other hand, the problem frequently was to match the sensitivity of the procedure used with permissible tolerances. Procedures having both adequate sensitivity and specificity were a problem throughout the survey. For instance, it was desired to detect phenol as low as 0.001 p.p.m. and to determine traces of oil.

It was necessary to compromise between those methods or procedures which most closely approached technical perfection and methods which were practical for the survey and for interpretation of the International Joint Commission, "Objectives for Boundary Waters Quality Control" (1). To meet this requirement, the chemical research laboratories of the Environmental Health Center and the Ontario Department of Health agreed on "Analytical Methods for Boundary Waters Quality Control" (2). Many of the techniques prescribed did not represent the best procedure available, but rather the best procedure which it was deemed feasible to specify.

Industrial Waste Treatment

Separate treatment of process wastes by the various industries, in the sense of rendering them acceptable for discharge to a natural watercourse, was provided to a very limited extent. The two outstanding examples were sedimentation for wastes from manufacture of caustic soda and partial neutralization of waste pickle liquor. Both of these systems are discussed in some detail in subsequent sections of this paper.

There were a great many systems for recovery of usable materials and for treatment prior to re-use. Although there was insufficient time to make economic studies of these various recovery processes, there was reason to believe that the great majority were sound investments. Typical of these installations were:

1. Clarifiers for blast furnace flue gas wash water to recover iron ore.
2. Paper mill save-alls for recovery of pulp.
3. Petroleum refinery oil-water separator (A.P.I. design).
4. Tar separators at coke and water gas plants.
5. Purification systems for lubricating oil and soluble cutting oil.

Closely allied with treatment of industrial wastes were the counter measures taken to obviate the need for treatment. During the course of this investigation, striking results in curbing pollution were observed by:

1. Adoption of department accountability measures on potential waste.
2. Metering of lubricating oil used.
3. Inauguration of good housekeeping principles.

Combined Treatment

The Detroit area supported many satellite industries. A great variety of industrial activity was represented, with more than the usual number of metal working and electroplating shops operating on subcontracts from the automotive industry. Industrial plants located in areas served by the Detroit sewerage system were allowed sewer connections for discharge of those liquid wastes which conformed to "Standards and Regulations Controlling the Discharge of Industrial or Commercial Type Wastes into the Detroit Sewer System" (3).

It was neither practical nor necessary for the purposes of this survey to investigate industrial plant effluents discharged to the Detroit sewerage sys-

tem. Instead, a study was made of the operation records of the Detroit sewage treatment plant to determine the effect of industrial wastes on plant operation. This was one phase of the over-all study of sewage treatment requirements for the area.

The Detroit sewage treatment plant provided primary treatment and final chlorination. It was estimated that the treatment plant served a total population of 2,300,000 during the survey period. Average data for raw and treated sewage were as follows:

Year	Flow (m.g.d.)	5-Day B.O.D. (p.p.m.)		Susp. Solids (p.p.m.)	
		Influent	Effluent	Influent	Effluent
1946	344.5	122	70	242	107
1947	370.4	111	56	202	91

Although the B.O.D. and solids data did not significantly reflect the presence of industrial wastes, chlorination was seriously affected. The city's objective in chlorine treatment was to satisfy 100 per cent of the effluent chlorine demand during the summer months and 60 per cent in the winter. Rapid fluctuation in demand and variable flow complicated chlorine dosage control. The chlorine demand actually satisfied averaged 66.8 per cent during 1946 and 58.8 per cent for 1947. The mean monthly maximum chlorine demand satisfied was 93.7 per cent, occurring in July, 1946. Chlorine demand of this sewage averaged 7.5 p.p.m. in 1946 and 6.3 p.p.m. for 1947.

Intermittent slugs of waste pickle liquor and iron salts created chlorine demands which exceeded the capacity of the available chlorination equipment. During these periods, which represented about 10 per cent of the time, chlorination of the final effluent was suspended. The duration of these individual slugs varied from 64 to 81 min. and increased the chlorine demand of the settled sewage from 7.6 to 10.8 p.p.m. above the normal demand.

A less conspicuous constituent was phenolic type material, which varied in the raw sewage from 0 to 630 p.p.b. Phenol curves for sewage received at the treatment works indicated phenol release by the industry over relatively short periods. The peak phenol concentration occurred between 6 A.M. and 9 A.M. on week days.

Pollutional Constituents Studied

Industrial waste surveys of some plants manufacturing similar products gave highly dissimilar results. This was particularly true of the by-product coke plants. In analyzing these data principal factors influencing the wastes have been examined. These factors are briefly described in the following discussion.

Phenolic Type Materials

Phenolic type materials originated primarily in the liquid wastes from production of by-product coke, refining of coal tar, and the manufacture of phenolic resins and other organic chemicals. Manufacture of water gas constituted a secondary source of phenol waste during severe winter weather, when domestic demand made it necessary to supplement the natural gas supply from the Texas Panhandle region. One impoundment area for water gas tar and another for gas plant tar separator effluent were a seasonal threat and on occasions were known to cause pollution. Minor phenol sources were recognized but not studied. Phenol accounted for is recorded by areas in Table I.

A. By-Product Coke

Four by-product coke plants located in the Rouge and lower Detroit River areas produced 62 per cent of the phenol. These coke plants were carbonizing a total of 10,800 tons of coal per day, representing 94 per cent of their 1944 peak production. Coke was

TABLE I.—Summary of Industrial Wastes Discharged Daily—United States Waters

Area	Gibbs Phenol (lb.)	Cyanides,[1] HCN (lb.)	Ammonium Compounds, NH_3 (lb.)	Oils (U.S. gal.)	Susp. Solids[1] (tons)	Acid Equiv. $CaCO_3$ (tons)	Pop. Equiv.[2] (1,000)
St. Clair River	0	0	15	40	31	0	348
Lake St. Clair	1,230	0	40	0	0	0	164
Detroit River	4,890	6,200	11,010	16,240	925	118	1,263
Total	6,120	6,200	11,065	16,280	956	118	1,775

[1] Based on I. J. C. and supplementary data.
[2] B.O.D. basis.

being supplied to local blast furnaces, foundries, and for lime kilns employed in the manufacture of soda ash by the ammonia-soda process. Some coke was produced for domestic use. The pollutional significance of coke plant wastes was considered justification for thorough studies of these four plants.

These by-product coke plants were all operating on high-volatile bituminous coal blends in the high-temperature carbonization range. The highest average flue temperature reported was 2,250° F. for blast furnace coke. The coking temperature is normally reduced some 300° F. in production of foundry coke. Flue temperatures in the vicinity of 2,500° F. are considered critical, above which the oven fire brick may be damaged. However, some coke ovens are reported operating with flue temperatures as high as 2,850° F.

The temperature of carbonization is the most important single factor in determining the yield and properties of coal tar and of each of the other primary products derived from destructive distillation of a given coal (4). These relations are well illustrated by Figure 5, taken from U. S. Bureau of Mines Technical Paper No. 584 (5). It follows that by-product coke waste characteristics will vary with change in coking temperature. Production of tar and tar acids decreases progressively with rise in temperature of carbonization, the decomposition products serving to enrich and to increase yield of the gas (4). The term "tar acids" includes all of the phenolic constituents of coal tar.

The volume of ammoniacal liquor produced per ton of coal charged is another major factor influencing the phenol content of by-product coke wastes. This liquor volume in turn depends primarily on the method used to recover ammonia from the coke-oven gas. Two methods are in use in the United States, the semi-direct and the indirect. The semi-direct process normally gives 15 to 25 gal. of ammoniacal liquor per ton of coal and the indirect process ranges from 35 to 90 gal. (6). These values are increased 25 to 50 per cent by addition of direct steam and milk of lime in the ammonia still to give the volume of still waste.

In both the semi-direct and the indirect processes, the hot gases from the ovens are cooled, thereby condensing a substantial portion of the ammonia, along with tar, as a dilute aqueous liquor referred to as weak liquor or ammoniacal liquor. The semi-direct process distills the ammonia from the weak liquor and returns it to the gas stream. The gas is then contacted with dilute sulfuric acid to produce ammonium sulfate.

The indirect process scrubs ammonia from the cooled gas with water in a series of counterflow ammonia scrubbers. The scrubber liquor is mixed with the condensate from the primary cooler and distilled. The gaseous ammonia from the still is usually con-

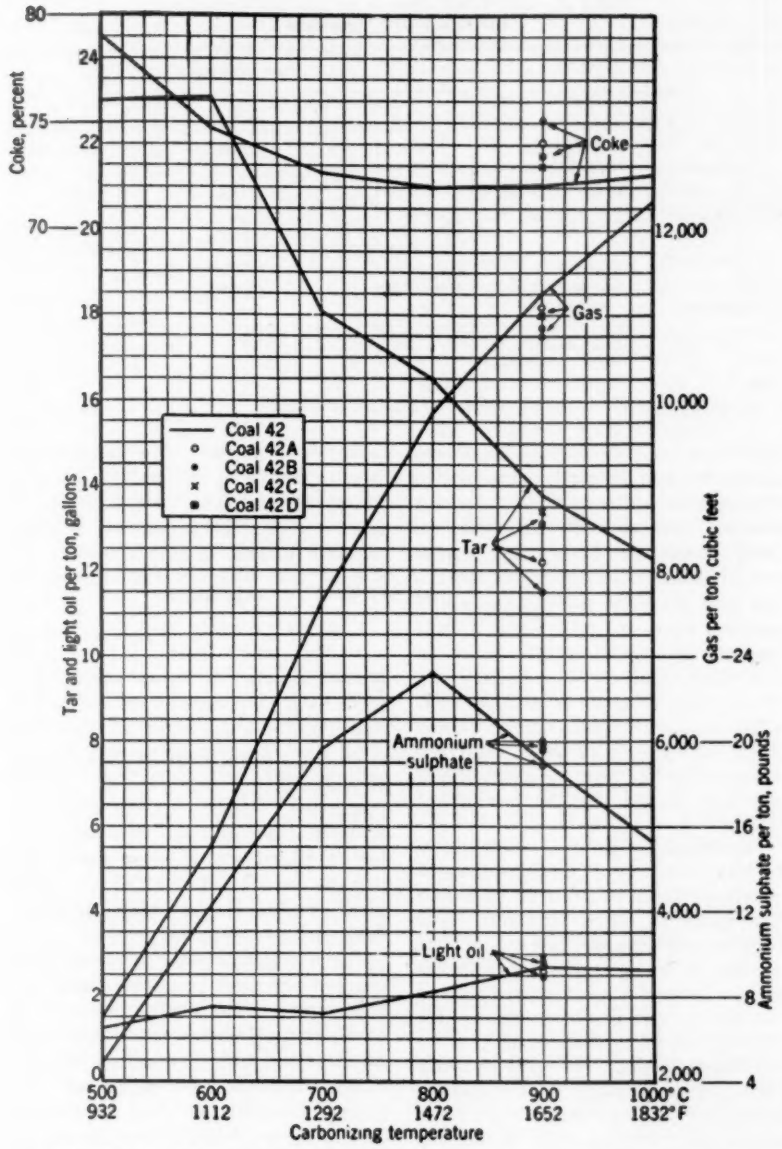

FIGURE 5.—Yields of carbonization products from Upper Banner Seam coal.

TABLE II.—Unit Values (Pounds per Ton Coal Carbonized) Correlated With Operations

Basic Information		Plant Designation		
		A	B	C
Constituent	Gibbs phenol	0.14	0.56	0.42
	Cyanide (HCN)	1.34	0.02	0.04
Operation	Coke type	Blast furnace and foundry	Foundry	Blast furnace and foundry
	Ammonia recovery process	Semi-direct	Indirect	Indirect
	Ammoniacal liquor (gal./ton coal)	20	42	62

verted to a concentrated ammonia liquor, but may be used in production of ammonium sulfate. The demand for ammonia liquor concentrate by the local alkali industry resulted in three of the four by-product coke plants in the Detroit area using the indirect process of ammonia recovery. In contrast to this practice, the semi-direct process is the most widely used by the industry. In recent years, as much as 86.5 per cent of the ammonia produced by United States coke plants has been recovered as ammonium sulfate for use as fertilizer and mostly by the semi-direct process (7).

The foregoing discussion will aid in the interpretation of phenol unit value variations shown in Table II. The fact that plant B waste contained four times as much phenol per ton of coal as plant A waste is attributed to the indirect ammonia recovery system and the lower coking temperature for foundry coke, notwithstanding other significant factors. The other two coke plants are designated "C" because the ammoniacal liquor was combined for distillation. Phenol unit values for plants A and C afford an excellent illustration of the influence which the volume of ammoniacal liquor has on the amount of phenolic constituents dissolved from the tar. This phenomenon is an example of the well-known law in physical chemistry pertaining to distribution of a solute between two immiscible solvents (Henry's law).

B. Coal Tar Distillation

Coal tar products were produced at one plant, which discharged wastes to the old channel of Rouge River. Tar from local by-product coke and water gas plants was subjected to fractional distillation using both batch and continuous stills. High phenolic wastes originated from batch decantation operations. It was found that approximately 80 per cent of the phenols were present in 2.7 per cent of the total plant wastes, a favorable condition from the standpoint of control.

The average phenol (in pounds discharged per day) from this plant was comparable to the smallest by-product coke plant. However, occasional batch decantation resulted in periods of 7 to 8 hr. when the rate of phenol discharged from this one plant was equivalent to the combined phenol discharge rate from all other known phenol sources in the Detroit area. This constituted a shock load of a highly pollutional material.

C. Plastics

Production of phenol-formaldehyde type resins at one plant in the metropolitan area resulted in phenol losses as high as 2,000 lb. per day, with an average of 1,230 lb. These wastes drained to the municipal combined sewers, in which they were normally conveyed to the Detroit sewer system and treatment plant. However, combined sewage overflows, during periods of surface runoff, released substantial portions of these wastes to a tributary of Clinton River.

It will be noted (Figure 3) that Clinton River discharges into Anchor Bay and merges with the western portion of the dominant current through Lake St. Clair. These geographical and hydrological features are significant because of municipal water supplies taken from Lake St. Clair and the fact that these waters reach the head of Detroit River in four to five days.

D. Water Gas

Capacity was provided in the Detroit area for manufacturing carbureted water gas at the rate of 60,000,000 cu. ft. per day. The gas was blended with and supplemented natural gas. The operating season seldom exceeded three months and capacity production, if reached, was sustained only during the coldest weather when demand was high.

Gas production was divided between four plants. One plant, equipped to produce one-third of the total output, discharged wastes to the Detroit sewerage system. Two of the plants discharged to Detroit River between Belle Isle and confluence of the Rouge River. The fourth plant drained to Rouge River.

During peak operation, wet tar was trucked to the Rouge River gas plant area from the other three plants and stored in earthen basins. This practice allowed additional time for gravity separation of water and tar. This procedure also relieved overloaded tar dehydration equipment at the other plants and permitted full utilization of more efficient equipment at the Rouge River plant. Based on short-time studies at two of these plants, the indicated maximum phenol pollution load from all three plants which discharged directly to streams approximated 350 lb. per day.

A smaller water gas plant was located at Marysville. Tar separator effluent at this plant was pumped to a shallow lagoon, where it was expected that oxidation would render these wastes innocuous. Normally this system did eliminate these wastes as a pollution source. It was observed, however, that surface runoff during and following heavy rainfall carried substantial quantities of phenol from this lagoon area. These intermittent discharges of phenol entered a small tributary to the St. Clair River.

E. Organic Chemicals

One Wyandotte industry produced a variety of organic chemicals including alkyl phenols. Liquid wastes containing phenol were diverted through a pond affording a theoretical retention of five days. There was virtually no reduction in phenol concentration during this storage period. Analysis of these wastes indicated a daily phenol loss approximating 220 lb. at a fairly uniform rate. This discharge entered Monguagon Creek, a small tributary stream of Detroit River, Trenton Channel.

Cyanides

Coke-oven gas final cooler water was the most important source of cyanide waste in the area. Other by-product coke wastes and blast furnace flue gas wash water contributed additional hydrogen cyanide. Metallic cyanides other than hydrogen cyanide occurred in wastes from surface cleaning of nonferrous metals, electroplating, and to a

limited extent from case hardening of steel. The summation of cyanide waste, determined and estimated, is given in Table I.

The highly toxic character of free cyanide, 0.05 to 0.1 p.p.m. CN being reported fatal to fish, caused significance to be attached to even small quantities of cyanide-bearing wastes (8) (9). Analytical work was confined to the cyanide radical, even though other cyanogen compounds were known to be present in the by-product coke wastes.

A. Coke-Oven Cyanide

Hydrogen cyanide (HCN) is the principal cyanogen compound in coal gas. It is frequently referred to in the literature as "cyanogen." However, cyanogen proper (C_2N_2) is present in coal gas in extremely small amounts, if at all (10).

Hydrocyanic acid is a weak acid, by comparison much weaker than carbonic acid. It is an extremely water soluble compound and accordingly may be expected in water condensed from the gas and other water that has been in contact with the gas. Its low boiling point (26° C.) and correspondingly high vapor pressure result in relatively rapid volatilization from dilute aqueous solutions, at a normal pH range, when agitated and exposed to the atmosphere.

Hydrogen cyanide in coal gas is a product of high coking temperatures and of secondary reactions (10). It is formed in coke ovens by the reaction of ammonia with carbon or such carbon compounds as acetylene. It has been shown that hydrogen cyanide production begins in coke ovens at about 600° C. and increases progressively with temperature rise, the rate decreasing at the higher temperatures. Ammonia production declines above 850° to 900° C. as a result of thermal dissociation and conversion to other nitrogenous compounds, chiefly hydrocyanic acid (11). There are other factors besides temperature believed to have bearing on hydrogen cyanide production, but their discussion does not come within the purview of this paper.

Unit values for hydrogen cyanide recorded in Table II show marked variation for these by-product coke plants. The value of 1.34 lb. HCN per ton of coal carbonized, for plant A at the time of the survey, is believed to be far above the average coke plant. However, during winter operation, with cooling water temperature approaching 0° C., the HCN unit value for plant A reached 2.1. Over 99 per cent of the HCN in plant A waste was in the gas final cooler water. This cooling water was discharged to a tributary stream some 3 mi. above confluence of Detroit River. The point of discharge was significant in that it allowed time for escape of HCN to the atmosphere and for conversion to less toxic cyanogen compounds before reaching the International Boundary Waters.

Discharge of gas final cooler water, as at plant A, is not conventional practice (7). Most semi-direct ammonia recovery coke plants employ closed systems recirculating this final cooler water after it has been cooled by adiabatic evaporation in a cooling tower. The indirect cooling system with coils provides an alternate for areas where emission of HCN to the atmosphere might create an air pollution problem. Plant A has recently installed a closed system and now cools the gas final cooler water by means of an indirect cooling system. This system has merit where the unpurified gas satisfies industrial requirements. However, when commercial gas is produced, increase of HCN in the gas places an added burden on the gas purification system.

The indirect ammonia recovery system used by plants B and C provides adequate cooling of the gas in the counterflow ammonia scrubbers, thereby obviating the need for final coolers

ahead of the light-oil scrubbers. However, the ammoniacal liquor of the indirect system absorbs more HCN from the gas than it does in the semi-direct process because of the larger volume and lower temperature. The ammonia still effluent was the principal source of cyanide waste from plants B and C. Some HCN distills over with the ammonia into the ammonia water concentrate. There is a strong tendency for thiocyanates to form in the ammoniacal liquor from HCN in the presence of sulfides and free ammonia. Thiocyanates have been reported as high as 2,000 p.p.m. in the still waste (6).

Other cyanide waste sources, of smaller quantities, were in condensates drained from the wash-oil and light-oil decanters in the by-products area. These condensates have been reported extremely toxic to fish. Coke quench water averaged 0.03 p.p.m. HCN.

B. Blast Furnace Cyanide

The HCN concentration of blast furnace flue gas wash water is relatively low, but still above that reported fatal to fish. Data for two blast furnaces studied gave an HCN range in concentration from 0.16 to 2.2 p.p.m. These results, correlated with flow and production, indicated an average of 20 lb. HCN daily in the flue gas wash water from a blast furnace producing 1,000 tons of pig iron per day. This value has been applied to pig iron production from these blast furnaces during the years 1946 and 1947 to give an average daily discharge of 75 lb. HCN from this source.

C. Metal Industries Cyanide

The quantity of cyanide waste from metal industry sources was of the order of 1 per cent of the total discharged in the area. Sodium, copper, and zinc cyanides were used in conventional plating operations. Detailed study of one electroplating plant revealed rinsewater maximum flow of 10 g.p.m., with the cyanide concentration varying from 6 to 214 p.p.m. (as sodium cyanide).

Plating tank contents were very rarely discarded. Occasions for wasting the concentrated solution were: leaks, discontinuance of process, and build-up of sodium carbonate. Controlled discharge was the most common method for disposal of spoiled cyanide baths.

Ammonium Compounds

The alkali industry was the principal source of ammonia waste. Substantial ammonia losses occurred at one by-product coke plant. Miscellaneous ammonia waste sources included: organic chemical manufacture, coal tar distillation, water gas, and plastics. Free ammonia and ammonium salts were determined, the results being summarized in Table I.

A. Alkali Industry

Inherent ammonia loss in manufacture of soda ash accounted for 70 per cent of the total ammonium compounds wasted. This waste was largely ammonium chloride and other relatively stable ammonium salts, which were not decomposed by steam and lime treatment in the strong ammonia liquor still. This loss represented roughly 25 per cent of the ammonia produced by the three coke plants employing the indirect ammonia recovery process.

B. By-Product Coke

One coke plant was responsible for 23 per cent of the total ammonia wasted in the area. This amounted to 0.56 lb. ammonia per ton of coal carbonized at this plant. These excessive losses occurred in both still waste and gas final cooler water. The ammonia concentration in the still effluent reached a high of 2,500 p.p.m., indicating inadequate lime treatment. Effluent from a properly operated ammonia still should not contain in excess of 500 p.p.m. ammonia and normally will

be less than 300 p.p.m. The high ammonia in the gas final cooler water reflected inefficiency in conversion to ammonium sulfate at the saturator. Ammonia losses for all by-product coke operations represented 26 per cent of the total.

C. Miscellaneous

Waste discharged from this group of industries was influenced by batch processes and, in the case of gas manufacture, by irregular operation. These intermittent releases of waste gave higher concentrations in the various effluents than the total ammonia loss would indicate. The outlets from these plants, with the exception of water gas, were to tributaries, which tended to smooth out these surges. Coal tar distillation and the plant manufacturing organic chemicals each averaged slightly less than 200 lb. of ammonia loss per day.

Oils and Greases

In a heavily industralized area, such as Detroit and environs, it will be appreciated that innumerable sources of waste oil existed. However, most of the waste oil originated at 13 industrial establishmens. In fact, 87 per cent of the total oil reported in Table I was discharged to Rouge River by one large automobile manufacturing plant. Waste grease and fats originated as residues from lubrication of machinery, at reduction works, and from manufacture of such products as hydrogenated glycerides (hardened fish and vegetable oils), free fatty acids, and glycerine.

Rolling mills for both steel and nonferrous metals contributed substantial amounts of oil to the boundary waters. Pressure lubricated roll bearings were a significant source of waste oil, losses being dependent largely on seal and packing maintenance. These oil losses were reduced somewhat by use of water-lubricated phenolic bearings. Phenolic bearings are made of either canvas or belting fabric impregnated with phenolic varnish, dried, trimmed to desired size, and molded to shape under heat and pressure. A second source of waste oil was that sprayed on the metal being rolled, where lubrication was necessary to preserve the metal and roll surface. A similar source was the emulsion formed from cleaning of strip, coated with oil subsequent to pickling.

Soluble oil (soda water) used for cooling and lubricating stock during threading, boring, and other machining operations represented a second major type of oil waste. It was common practice to discard this emulsion following varying periods of use and for any one of the following reasons:

1. Sludge build-up.
2. Accumulation of lubricating oil.
3. Rusting of stock.
4. Dermatitis affecting workmen.
5. Objectionable odor.

Plant-scale demonstrations indicated that improved disinfectants and effective purification systems would permit extended re-use of soda water. Purification systems employed included: filtration, flotation, centrifuging, and plain sedimentation.

Large-scale mechanical operations made lubricating oil losses inevitable. These losses were controlled in proportion to the operation and maintenance effort expended within the plant. Installation of pans beneath machines recognized as chronic "oil leakers," proved beneficial. The benefits to be derived from detailed "oil surveys" were clearly demonstrated.

Miscellaneous greases and fats were relatively small pollution sources as compared with oil waste. The largest single source was one plant, where railroad tank car quantities of crude vegetable and fish oils, and soap liquors from soap manufacturers were processed to give glycerine, hydrogenated glycerides, and free fatty acids. The conversion of soaps to free fatty acids

resulted in batch discharge of wastes from one oil trap having concentrations of ether-extractable materials (oils, greases, and fats) as high as 3.8 per cent. Survey data indicated a daily loss of approximately 3,900 lb. of dry solids from this plant, consisting principally of the salts of valuable fatty acids.

Oil films on the lower Detroit River were a constant threat to water fowl. It was not uncommon to see oily wastes discharged to Lake St. Clair from county drains, with resultant damage to pleasure craft. Storm-water overflow to Conner Creek likewise frequently carried slugs of oil.

Suspended Solids

The alkali industry was the major source of suspended solids. Other significant sources included: automobile manufacture, rubber tire production, cement plant, integrated steel mill, and salt manufacture. These six industries produced 90.5 per cent of the suspended solids wasted to United States boundary waters and tributaries. Suspended solids losses are reported by areas in Table I.

A. Alkali Industry

Large quantities of calcium carbonate, as a filter cake, were produced in manufacture of caustic soda. A portion of this calcium carbonate was used locally in production of cement, but the surplus was considerable. Large slurry lagoons, located on Zug Island, Fighting Island, and Grosse Ile were used for removal of the coarser solids. One plant, with inadequate sedimentation facilities, wasted in excess of 600 tons of suspended solids daily to the lower Detroit River, essentially as calcium carbonate slurry. Suspended solids entering the boundary waters from three alkali plants amounted to 74.5 per cent of the total for the area, or approximately 700 tons daily.

The total solids wasted to the boundary waters by the alkali industry approximated 6,500 tons daily. In addition to calcium carbonate, these wastes contained calcium chloride, unreacted brine, and some calcium sulfate formed from the sulfate impurities in the brine.

B. Automobile Manufacture

Suspended solids from one self-contained automobile manufacturing plant included: iron oxide mill scale, iron ore, coke fines, and paper pulp. Highly diversified manufacturing operations created innumerable other sources of suspended solids in liquid wastes of importance in aggregate. These wastes represented 7 per cent of the area total, approximately 65 tons of suspended solids daily.

C. Integrated Steel Mill

Mill scale, iron ore, and coke fines were the principal solids in these wastes. Based on similar plants, these suspended solids were estimated to total 64 tons daily. One-third of these solids was discharged to Detroit River from Zug Island and the remainder approximately 2 mi. downstream.

D. Rubber Tire Production

These solids were largely soapstone slurry losses from the plasticators and the mills, and carbon black from the Banbury mixers. Occasional overflow was reported from the slurry storage tanks. Suspended solids from this plant averaged 22 tons daily.

E. Cement Plant

Stack washers were used in conjunction with a multicone dust collection system. Limestone and clay dust amounted to as much as 22 tons per day in this stack washer water. This waste entered the old channel of Rouge River.

F. Salt Manufacture

Sludges from brine treatment were discharged intermittently. Approxi-

TABLE III.—Acids Discharged Daily to United States Waters

Plant	Materials Discharged		$CaCO_3$ Equivalent[1] (lb./day)
	Type	(lb./day)	
A	H_2SO_4	16,800	17,500
	$FeSO_4$	27,800	18,300
B	H_2SO_4	12,000	12,500
C	H_2SO_4	550	570
	$FeSO_4$	178,000	117,000
D	H_2SO_4	75	80
	$FeSO_4$	4,100	2,700
E	HCl	42,000	57,500
F	HCl	2,300	3,100
G[2]	H_2SO_4	1,900	2,000
H[2]	H_2SO_4	450	470
	$FeSO_4$	2,300	1,500
J[2]	H_2SO_4	320	330
	$FeSO_4$	1,600	1,050
K[2]	H_2SO_4	320	330
	$CuSO_4$	420	260
L[2]	H_2SO_4	450	470
	$CuSO_4$	580	365
Total			236,020

[1] Computed on basis of sulfate.
[2] Weekly and monthly dumping converted to daily basis.

mately 15 tons of calcium sulfate, in a very finely divided form, were discharged over a 4- to 5-hr. period daily into St. Clair River. Every three weeks some 90 tons of calcium carbonate and 19 tons of magnesium hydroxide, as a 10 per cent slurry, were flushed to Pine River during a 5-hr. period.

Acids

Significant quantities of acid wastes were discharged from 11 manufacturing plants. Waste pickle liquor was the principal source, accounting for 68 per cent of the total recorded in Table III. With the exception of the two plants processing non-ferrous metals, these acid wastes entered Detroit River through and downstream from confluence of Rouge River.

One company operating at two locations along the lower Detroit River (plants C and D, Table III) neutralized most of the free acid present in the pickle liquor. It will be noted in Table III that the hydrolyzable sulfate in the partially neutralized waste still represented considerable acidity. Sludge resulting from lime treatment was discharged along with the partially neutralized liquor.

The two plants manufacturing copper and brass products discharged to Detroit River approximately 2 mi. above confluence of Rouge River. Most of the pickle liquor tanks used in cleaning non-ferrous metals were on a 30-day dumping schedule, although some liquors were used 90 days before wasteing. Dissolved salts were primarily copper sulfate, with lesser amounts of zinc sulfate.

Hydrochloric acid wasted by plant E was an abnormal condition. This acid resulted from substitution of sodium chloride for soda ash in process during a temporary shortage of soda ash.

Waste pickle liquors were usually dumped over relatively short periods. Concentrations of these pollutional materials in the receiving waters thus reached levels far above those indicated by the average daily discharge. These slugs of acid wastes were readily detected by color for considerable distances below the points of discharge.

In connection with these acid wastes having a calcium carbonate equivalent of 118 tons daily, it is of interest to note that the alkali industry in the Detroit area wasted daily to Detroit River approximately 700 tons (dry solids) calcium carbonate as a slurry. The high dilution available and the shoaling tendency of these solids re-

sulted in only local increase in alkalinity of the receiving waters.

Biochemical Oxygen Demand

Waste from manufacture of sulfite pulp and paper was the largest source of B.O.D. in the area. Other wastes having significant amounts of B.O.D. included those from a large plant manufacturing automobiles, production of plastics, and from a beet sugar factory. A large miscellaneous group of industries produced wastes having varying amounts of B.O.D. The population equivalent of 1,775,000 (B.O.D. basis) given in Table I, which does not include the material dredged from Rouge River, is believed to be a conservative value.

A. Pulp and Paper

Two sulfite pulp and paper mills produced wastes having a population equivalent slightly in excess of 1,000,000. Approximately one-third of this pollution load was discharged to Black River some 1.5 mi. above confluence of St. Clair River; the other two-thirds entered the old Rouge River Channel in the Zug Island area. These wastes represented 58 per cent of the total B.O.D. originating from industries operating on the U. S. border.

The highly pollutional digester liquor, with an average 5-day B.O.D. of 45,000 p.p.m., accounted for 80 per cent of the B.O.D. from these pulp and paper mills. This sulfite liquor contained dissolved organic matter representing the noncellulose constituents of the wood, which include lignin and carbohydrate or sugar substances originating in the hemicellulose. The sulfite pulp mills produced 96 per cent of the pollution load from this industry and the adjoining paper mills only 4 per cent.

B. Automobile Factory

The industrial wastes discharged from this plant had a population equivalent of 280,000 or 16 per cent of the total for the area. These wastes entered Rouge River approximately 3 mi. above confluence of Detroit River. This pollution problem was complicated by the heterogenous character of the wastes and the magnitude of the plant.

C. Plastics

The average population equivalent of wastes from this industry was 80,700. This represented 4.5 per cent of the area total. A substantial portion of this waste resulted from manufacture of phenolic resins. Normally, discharge was to the Detroit sewer system. Combined sewage overflows allowed release at times to a tributary of Clinton River.

D. Beet Sugar

This factory produced a seasonal waste with an estimated population equivalent of 80,000, or 4.5 per cent of the total. Discharge was to Clinton River.

E. Miscellaneous

The remaining 17 per cent of the B.O.D. originated from a great variety of industrial operations. Although the pollution caused individually was relatively small, the combined population equivalent of 300,000 was significant.

Special Studies

Dredging Operations

The lower Rouge River, with its low velocities, was susceptible to shoaling. These solids were largely of industrial origin intermixed with sewage solids and alluvial material. The high rate of accumulation resulted in an annual program of maintenance dredging essential for navigation. These dredging operations were conducted each summer for a period of approximately 50 days.

Dredging was performed with a hopper dredge having a capacity of 935 cu. yd. Dredged material was dumped into the Detroit River at the head of Fighting Island, some 300 ft. west of the International Boundary Line and 1.5 mi. downstream from confluence of the Rouge River. The operation schedule was such that 10 trips were made each 24-hr. day.

The average daily discharge of dredged material to Detroit River contained 11.4 tons of iron (Fe), 17,400 gal. of oil, 2,700 lb. of sulfides, 325 tons of volatile solids, and a B.O.D. population equivalent of 373,000. These operations resulted in the transfer of a heavy mass of pollutional material from a tributary to the boundary waters. The pollutional effect of this material was traced 3.2 mi. by increases in coliform organisms, chlorides, and turbidity.

Overflow from the dredge hoppers carried approximately half of the solids pumped. This overflow, together with bottom disturbance, caused a substantial increase in solids discharged from the Rouge River. This in turn was reflected by an increase in shore pollution of Detroit River extending from 400 to 900 ft. from shore and for approximately 4.5 mi. downstream.

Navigation Wastes

Passenger and other vessels navigating the Detroit River, Lake St. Clair, and St. Clair River, or any part thereof, carried nearly 3,000,000 persons during the 1947 navigation season. The greatest concentration of vessel commerce occurred on the Detroit River, where total vessel passages exceeded 28,000, representing a net tonnage of 99,000,000. Freighters plying St. Clair River and Lake St. Clair transported 77,000,000 net tons.

Some large passenger boats and ferries were equipped with retention tanks for storage of sanitary sewage while at dock. It was customary to empty these tanks only in the Great Lakes at points remote from shore. Although this practice protected the harbors, it contributed masses of sewage in limited areas along the navigation routes. Other vessels following shortly thereafter could draw this contaminated water for drinking and culinary purposes. Freighters plying these International Boundary Waters discharged sewage promiscuously, a distinct health hazard in the vicinity of water intakes and bathing beaches. The population equivalent of navigation sewage for these boundary waters was estimated to average 3,900 at the height of the navigation season.

Garbage accumulation was estimated to average 2,000 lb. per day during the peak of the season. Navigation companies reported that garbage and refuse were stored in containers and subsequently disposed of at shore points or on the Great Lakes. It was not uncommon to see floating garbage on these boundary waters.

Bilge water included seepage through the hull, leakage in water lines and from pumps and machinery, and washdown water. It accumulated at the lowest level of the vessels and contained lubricating oils, greases, and like wastes. This mixture was discharged intermittently by the bilge pumps and was frequently the source of an iridescent oil film trailing freighters. Based on records of bilge pump operation and of oil consumption, oil thus discharged was estimated to be about 40 g.p.d.

Ballast water constituted another pollution source of variable significance. Common practice was to take on ballast water while unloading and to discharge it as cargo was received. It was not uncommon to pump ballast water overboard while en route to lighten the load and to increase the speed. Thus, grossly polluted water taken aboard at one point was transferred occasionally to zones of cleaner water.

PROGRESS IN POLLUTION CONTROL

Progress and control or elimination of pollution was substantial during the period of the investigation. The factors contributing to advancement were availability of materials following termination of World War II, stimulation by state and provincial authorities and interest of sportsmen's organizations and the public generally, research into waste disposal methods, and the activities associated with the investigation. At the time hearings were held by the I.J.C. in 1949, it was estimated that about $5,000,000 had been spent by industry on corrective measures since the investigation started. This corrective activity is continuing at substantially the same level at the present time.

Industries have shown a willingness to cooperate with the Commission and state and provincial agencies in solving the problems. Similar cooperation has been shown by municipalities, but it has been less productive largely because of financial difficulties.

Continuing Program

Application of the "reasonable use" doctrine to these waters requires that industrial waste control programs provide treatment sufficient to prevent destruction or impairment of water for other normal uses. Such treatment must be adequate not only for the present, but also must insure that new industries or new industrial processes will not jeopardize the rights of other legitimate water users and at the same time will be permitted to utilize their fair share of the water resources for waste disposal purposes. This is industry's obligation and it must continue to proceed with research and planning required for bringing and keeping this problem under proper control.

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DISCUSSION

By L. A. Danse

Chairman, General Motors Industrial Waste Control Committee, Detroit, Mich., and Industry Member, U. S. Water Pollution Control Advisory Board

The complexity of the problems which arise in a heavily industrialized area, such as that mentioned, are rendered more difficult by virtue of the fact that this region is along the border between the two nations. Notwithstanding the fact that both the Ontario provincial authorities and the Michigan-Ohio state authorities have been pressing the needs of the area, stark realism forces the admission that the local people, both municipal and industrial, have to some extent temporized and procrastinated; pointing the finger at the fellows over the border.

This situation made it all the more necessary that the work of the International Joint Commission should be prosecuted diligently and impartially.

It is a matter for deep gratification that this paper attests the determined and thorough nature of the engineering investigation conducted.

The well-planned and well-organized nature of this paper is typical of the care taken and the effort exerted to set up and to carry through the boundary water survey. Those of us who live and work in the Border Cities feel indeed fortunate to have had the caliber of engineers and the completeness of coverage of their work.

It has been noteworthy to follow the survey and hearings and to observe the change in attitude of the communal thought. As the work progressed, the great care with which it was being carried out impressed all concerned. And the uncompromising fairness of the participating engineers sold a lot of people who had been inclined to dodge the issue.

Industry in the border area soon responded to the evidences of impartiality, fairness, and dire need, as developed by the Commission; so that it was generally agreed that here was the sort of group to get the job done; and here, also, were fair solutions for the difficulties.

Having had the pleasure of hearing two of the resident engineers-in-charge report the progress of their work, the General Motors Industrial Waste Control Committee went on record in approval and helped spread the leaven through the industrial community by mention of the energy, enthusiasm, and foresight of those in charge.

The pattern set by the survey crews was extremely valuable to industry in demonstrating the procedures essential to acquiring adequate information upon which to base recommendations for control measures. The logical proofs offered of the effects of industrial wastes upon the public waters surmounted all objections and carried conviction to the public as well as to industry. Discussion with industries, backed by previous study of the processes involved, left no stone unturned in developing sources of pollution. Stream surveys were so well laid out and so well checked that tracing both the sources and the effects of pollution was assured. Study of existing treatment facilities thoroughly established the conditions of their operation.

The candor with which pollutional loads, constituents, causes, and results were outlined and evaluated left little doubt that here was an organization which could—and would—clean an augean stable.

While few industrialists would be inclined to oppose the survey or go contrary to the recommendations of those in charge, the minute details of

the investigations and checks reported were overwhelming in their significance that now there was to be a blueprint and all that devolved was to follow it and clean up.

Particular interest inheres in the mention of "Special Studies." Here, again, is evident the fine-toothed comb; and, again, the fairness of the evaluation of the problem.

The expressed sentiments of many industrial executives after being informed regarding the boundary water survey were that here was a group that was laying out a route which would be safe and sure for industry to follow.

DISCUSSION

By A. D. McRae

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Dr. Berry has given a very precise presentation on the findings of the Canadian section covering the survey of industrial wastes in the Lake Huron-Lake Erie section of the international waterways. The survey, in itself, was a tremendous undertaking, which required more than two years to complete and employed the services of the combined staffs of both federal and provincial public health engineers and chemists. Subsequent to this survey, Canadian industrial representatives were invited to attend public hearings at Windsor, Ontario, in November, 1948, to discuss ways and means of abating the discharge of industrial wastes into boundary waters. The International Commission and the Board of Technical Advisers are to be commended for the way in which these hearings were conducted. The Commissioners listened to a large volume of evidence and statements and a spirit of cooperation prevailed throughout the three days of the hearings. In general, Canadian industry has a fairly concise plan for abatement of pollution and it was indicated that large sums of money were spent in the past and would be spent in the future to insure that the above waterways would remain suitable for wild life, fishing, bathing, drinking water supplies, and service water for industry.

It is reassuring to note that taste and odor problems have been practically eliminated since the start of the survey of the above international waters in 1946. Shore line contamination has been reduced considerably. These improvements, it is felt, have been due to the concerted efforts of United States and Canadian industry to reduce the discharge of deleterious substances in order to conform to the Commission's objectives for boundary waters quality control.

A total of $3,000,000 was estimated for control of pollution for Canadian industry. This estimate was made in 1948, and is now considered somewhat conservative due to increased costs of materials and labor. However, industry will keep faith with the Commission and will carry out its promises to the best of its ability. Since 1944, a great deal has been learned from authorities on sanitary engineering and those in public health work. The field engineers conducting the survey in 1946 were given an opportunity of studying the varied industrial processes which border on the international waterways. A "cards-on-the-table" attitude by Canadian industry was the rule rather than the exception. In turn, the technical staffs in industry became acquainted with many new aspects of the science of sanitary engi-

neering and they have applied this knowledge in programs of judicious waste disposal. In the larger industries, specialists in industrial waste disposal and conservation have directed the activities of pollution abatement. In many cases the monetary gain in reduction of pollution is a secondary consideration.

Public opinion is of paramount importance and today industry considers itself lucky if it can break even for expenditures on pollution abatement. Many methods of production have been altered since 1946, in order to reduce the pollution load on boundary waters. In conjunction with these changes, utilization of by-products has been accomplished and many waste materials have been eliminated. It is interesting to note that in the distilling industry, 1 bu. of grain will yield 1.2 bu. of cattle food, which was formerly discarded as a waste material. The petroleum refining industry is considering the use of cooling towers for service water, even in areas where water is plentiful, in order to reduce the temperature and volume of waste water. A program of diversion of clean cooling water has reduced the volume of water through terminal oil separators, giving a much lower oil content in the water discharged. Taste- and odor-forming components have been impounded, and the use of biological oxidation is being seriously considered for the complete destruction of these components. As the international waterways have a very rapid recovery in dissolved oxygen content, it is reassuring to know that some oxygen consuming wastes can be discharged judiciously and without affecting the oxygen balance of the river.

Each industry has recognized the danger of discharging sanitary sewage in trade wastes; in many cases this sewage has been diverted to municipal sewers or septic tanks. If this has not been done already, industry has made plans to make the diversion as soon as the municipalities have decided on the route of sanitary sewers to the proposed sites of sewage disposal plants.

It is felt that industry should follow up the individual programs of pollution abatement by means of meetings of representatives interested in waste disposal. Recently, the first industrial waste forum in Canada was inaugurated at the 17th Annual Convention of the Canadian Institute on Sewage and Sanitation. At this forum representatives from the distilling industry, synthetic rubber, and petroleum refining gave papers on waste disposal in their respective industries. It is suggested, also, that possibly quarterly meetings of industrial representatives could be held at various points in Ontario to discuss mutual problems in waste disposal and pollution abatement. A plan for efficient waste disposal in industry will confer benefits on the plant that is wise enough to institute a thorough study of the problems involved in the treatment of wastes. A program of good housekeeping will be in accord with federal and provincial programs of pollution abatement. Also, development of by-products and a better understanding of production efficiency will result from anti-pollution activities.

Industry feels that it should participate in an advisory capacity in the formulation of policies and the solution of technical problems involved in setting up control limits on pollution. The pollution abatement program is of necessity long-ranged, because of the complexity of waste materials and the research required to develop methods of treating these wastes. In comparison, the handling of sanitary sewage is a somewhat simple affair and government agencies and the public will have to be patient while industry works out its own solution.

THE OPERATOR'S CORNER

CONDUCTED BY HERBERT P. ORLAND

CITY HALL RELATIONS

In a panel discussion on "Public Relations Between City Officials and Their Water and Sewage Works Operators," presented at the 1950 Annual Meeting of the South Dakota Water and Sewage Works Conference, there was considerable thought-provoking comment both by the panel members and by individuals in the audience. A few points made are worthy of further emphasis here.

Two mayors on the panel brought out the fact that a more satisfactory working arrangement could be achieved if they could have closer cooperation from the operator in being kept advised as to plant condition and the operator's needs, and if the operator would attend council or commission meetings to become better acquainted with the governing officials.

One panel member pointed out that "at least once a year all the city officials visit all of the various municipal installations of the community." We should hope so—and that they do not feel overly acquainted with conditions at the plants by reason of an annual visit!

Another point emphasized in the discussion was that incoming councilmen or other city officials generally are entirely unfamiliar with the plants and it behooves the operators to immediately acquaint them with the installations, their operation, and what the operators are doing to provide efficient, satisfactory service.

All this can be summed up in one short statement: "The operator must take his problems to the city officials and not wait for them to come to him." Very few councilmen, commissioners, or even mayors will come seeking the troubles they have entrusted to the operator unless those same troubles are called to their attention, usually by irate citizens who feel they have legitimate complaints. By that time much good will has been damaged, if not sacrificed altogether. How much better to forestall all this by being forehanded in laying the difficulties before the proper authorities.

The simple acts suggested herein would seem so obviously to be functions of the operator's job as to need no comment. However, it is human nature to overlook the obvious under the pressure of daily problems. No operator wants to become known as a chronic nuisance to municipal officials. However, a forthright, sincere effort at acquainting those same officials with the "why's" and "wherefor's" of plant operation and maintenance requirements, not to mention additions and improvements, is certainly a worth-while one.

All too often an operator spends much of his time trying to build good public relations, only to neglect almost to the point of ostracism some of his most valuable relations—those at the city hall. Are you doing all you should to make the "why's" of your needs known to those who hold the purse strings?

H. P. O.

SETTLING TANK WEIR CLEANER

By Floyd A. Gerard

Senior Civil Engineer, North Side Sewage Treatment Plant, Sanitary District of Chicago, Skokie, Ill.

Accumulation of floating debris and growths on the weirs of final settling tanks causes poor distribution of flow and makes a very unsightly tank surface. The problem of cleaning these weirs and keeping them clean has always been a tedious and time consuming task. It was solved, however, at least as far as the Sanitary District of Chicago was concerned, by a simple mechanical weir cleaner.

In 1936 the District placed in operation at the North Side sewage treatment plant twelve 75-ft. diameter final settling tanks. These tanks were equipped with rigid weir wipers of rubber belting attached to the sludge removal mechanism by a steel frame. The original rubber wipers wore rapidly and were soon useless, because the weirs were not concentric with the center pier and mechanism. In turn, several different types of cleaners were built and tested. Some were too complicated and expensive to build; others wore very rapidly and failed to remove the growths and debris. Finally, a very simple weir cleaner was developed and has been in use ever since.

It consists of two lengths of used

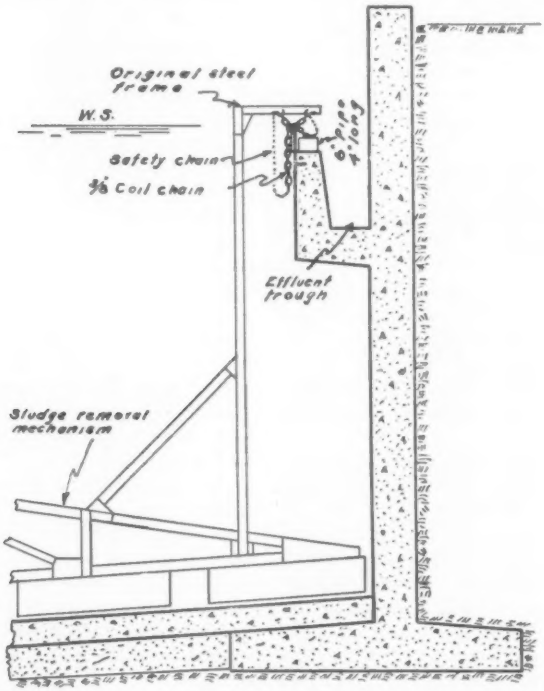


FIGURE 1.—Simple chain and pipe device attached to sludge removal mechanism cleans effluent weirs mechanically.

⅜-in. coil chain about 2 ft. long attached to hooks on the original steel frame. These chains are crossed and ride on top of the weir. Attached to the trailing end of the inner chain, which crosses over the top of the weir, is a piece of 6-in. pipe about 4 in. long (see Figure 1). This pipe rides upright on top of the concrete ledge and has a tendency to pass around obstructions and remain on the ledge. A third length of chain is hung from the walkway so that it wipes the outside of the influent well baffle as it rotates. The scraping or wiping action of these chains and the pipe keeps the weirs and surface of the tank clear of growths and unsightly debris. The positions of the chains are changed yearly to distribute the wear. Light safety chains are attached to the trailing ends of the cleaning chains so that they can be recovered should they wear through. It is estimated that the life of the chain is approximately four years.

This weir cleaner was so satisfactory at the North Side plant that a "twin" version hanging from a single arm was adapted to the concentric double weirs of the final settling tanks at the West-Southwest sewage treatment plant. With a little study this type of cleaner could be adapted for use on any style of weir or effluent channel.

These simple but practical devices were devised by the writer under the direction of J. R. Palmer, engineer of plant operation, and have solved a very perplexing problem and saved many hours of labor.

1950 OPERATORS' FORUM *

C. C. LARSON, *Leader*

Chemist, Springfield Sanitary District, Springfield, Ill.

Sampling Technique

Gail P. Edwards, Professor of Sanitary Chemistry, New York University, New York City (formerly, Chief of Laboratories, Department of Public Works, City of New York):—In sampling and analysis procedures there is no question but that sampling is much more difficult and unsatisfactory. Night sampling, of course, is notoriously bad.

With the shortage of men during the war, a new system was tried at one of the small activated sludge plants in New York City. Instead of getting 12 or 24 rather indifferent samples during a day, a program of concentrating on a few properly collected samples was started. The day was divided into four parts according to flow.

It happened that at this particular plant, which had a flow of about 16 m.g.d., 4 m.g. was received between 8:00 A.M. to 2:00 P.M., another 4 m.g. from 2:00 to 7:00 P.M., another 4 m.g. from 7:00 P.M. to 12:30 A.M. and the fourth 4 m.g. between 12:30 and 8:00 A.M. The medians of those flows came at about 11:00 A.M., 4:00 P.M., 10:00 P.M., and 4:00 A.M.

Arrangements were then made for the watch engineer himself to pick up the samples on his regular tours of inspection. In order to make the schedule coincide with his tours of inspection, the sampling hours were changed slightly from the median times. Thus, the samples were picked up at 10:00 A.M. and 3:00 P.M. (both during the

* From transcript, Twenty-Third Annual Meeting, Federation of Sewage and Industrial Wastes Associations; Washington, D. C.; October 9–12, 1950. [The remainder of the Forum discussion, covering the subjects of "Public Relations" and "Effect of Synthetic Detergents on Sewage Treatment Plants," will appear in an early issue.—Ed.]

day watch), at 10:00 P.M. (night shift), and at 5:00 A.M. (swing shift).

The procedure is not recommended for raw sewage sampling, which is bad, no matter how it is done. Probably 24 hourly samples would be better, in this case, even if they are poorer than the four good ones.

We were a little doubtful as to whether the sampling scheme would work out for primary settling tank effluents. In other words, with a 1-hr. or 2-hr. detention in primary tanks, it was a little questionable whether the short period would offset the differences that might be expected in the flows. However, it was thought that it might work out very well for aeration tank effluents or for final tank effluents.

The revised sampling program was begun with everything except the raw sewage. To our satisfaction, the values smoothed out and became much more consistent than ever before. The program worked out so satisfactorily that even with the return of operators after the war this system of sample collection was continued at that particular plant. One advantage is that the four samples are automatically proportioned according to flow.

Of course, the most important thing about such a scheme is that the samples must be taken by a trustworthy, interested, reliable, and trained person, such as the watch engineer. Just to substitute a few poor samples for a lot of poor samples is not a solution. However, substitution of a few good samples for many bad ones is certainly an improvement. There is no question but what it would be more advantageous to get 6, or 12, or 24 good samples a day. Nevertheless, under the circumstances, it had worked out very well indeed.

This system probably would not be satisfactory for a large plant. Obviously, it will not work out too well where the plant superintendent has so much administrative work that he may or may not get out to get the regular samples, or if the plant is so large that it would take him a good many hours to make the rounds. However, in a smaller plant, such as the one mentioned where the flow was about 15 to 16 m.g.d., it did work out quite satisfactorily.

As to automatic samplers, our experience has been that, although the sampler itself may be satisfactory, the flow to it must be representative or a poor sample will be obtained. For example, we sampled out of a 72-in. settled sewage line. The outlet from the line was at the perimeter of the pipe and the samples obtained did not check with any previous experience or with what was known to be the condition. Of course, if the sample is taken at the bottom, it will be heavy; if obtained on the side or near the top, it will be lighter.

A great deal of care must be taken to select a good sampling point. For example, too much turbulence must be avoided. I have seen sampling places that looked as though they would be very satisfactory, but the turbulence was so great that a laborer couldn't handle a sampling pole. If he were told to take a sample there his effort would be half-hearted and the sample would almost always be very poor.

It cannot be overemphasized that the whole sampling job must be done in the easiest way possible to get a good sample. Making it difficult makes it almost certain that the directions will not be carried out—except while the man is being watched. Of course, the best time to find the sampling point is when the plant is being designed.

A very good example of this condition was observed at New York's Wards Island plant. As the plant was originally designed, there were effluent weirs at both ends of the final settling tanks. These troughs discharged to channels, which merged and dropped at a manhole. It looked like a very good place, but actually we almost never got a sample from both channels. It always

came from one channel or the other. The condition became very apparent a little later on when some changes were made in the final tanks and 90 per cent of the effluent came through one channel. However, because it was easier to get a sample of the 10 per cent side, that is the one that was sampled. The smaller flow might have 30 or 40 p.p.m., whereas the larger flow might have 8 or 10 p.p.m. Still, very often, when the samples went to the laboratory there would be 30 p.p.m. of suspended solids, although, obviously, that was incorrect. It is not practical to collect a sample of the combined flow.

Thus, it should be emphasized that whether the sample is taken automatically or manually a good sampling point is necessary.

The words "good" and "bad" have been used in reference to samples. To me, a good sample is a representative sample. It represents what is going out of the plant or through the section of the plant being sampled. There is a wide divergence of opinion among operators as to what is a good sample and what is a bad sample. We have tried to get samples of primary sludge, for example, by taking them out of a pump. Now, a laborer's concept of a good sample seemed to be one that had anywhere from 10 to 20 per cent solids. As soon as the pump was started the first slug would be very heavy, and that is what he would collect. We had to eliminate sampling from the pumps for that reason, because the laborers' idea of a good sample and ours didn't check. A good sample is a representative sample.

E. G. Studley, Principal Civil Engineer, Los Angeles, Calif.:—I assume that these samples are on a 24-hr. basis and that they are kept on ice?

Dr. Edwards:—That is correct. The samples are brought directly into the laboratory. The sampling day runs from 8:00 A.M. to 8:00 A.M.

Mr Studley:—So far the discussion on sampling has to do with the liquids. What is your technique for the sampling of filter cake and dried fertilizer?

Dr. Edwards:—We don't happen to have either one of those at any of our plants. However, we do have our troubles with sampling sludge. At Wards Island, for example, there is a quick-opening valve on the line discharging from the storage hoppers to the sludge vessels. The men are instructed that every 10 min. during the loading of a boat they are to give that quick-opening valve a jolt and get a sample in a bucket. They do pretty well—if they are watched.

Thomas E. Robertson, Superintendent, Sewage Treatment Plants, Spartanburg, S. C.:—Mr. Edwards, you stated that it wouldn't do to take a sample where there is too much turbulence. At Spartanburg we have designed an automatic sampler which we think is about as good as can be. This machine works on the principle of the old-fashioned paddle wheel and the whole machine rides on floats. Of course, as the flow increases the velocity increases, causing the machine to collect samples in proportion to flow. I can see your point in taking a hand sample, but this machine rides at flow level and is sampling on a continuous basis. However, a shallow weir is installed in channels where needed to maintain the proper depth at low flows.

Dr. Edwards:—You are quite right; my comments apply to hand samples. The difficulty was really one of a man holding a pole to get a sample in a bottle out of a bay where the velocity and the turbulence were so great that he really couldn't handle it. But for mechanical sampling I think turbulence would not be a disadvantage.

Mr. Robertson:—I have found, by trying at various points, that just where the clarifier channel discharges into the effluent pipe is an ideal point to secure a sample.

Clarence E. Keefer, Deputy Sewerage Engineer, Bureau of Sewers, Balti-

more, Md.:—What do you use to prevent the formation of fungus and other growths in the pipe of your sampling machine?

Mr. Robertson:—We take two samples a week, on Tuesday and Thursday. Every week the tubing is cleaned with a wire brush such as is used for cleaning a .22-cal. rifle barrel. The ⅛-in. brass pipe is then washed out thoroughly. At first it was thought that there would be trouble with clogging of the machine by raw sewage, but so far this problem has been negligible.

John W. Johnson, General Manager, Buffalo (N. Y.) Sewer Authority:—The gentlemen from Los Angeles asked a question about sampling of sludge cake and fertilizer. I might offer him a suggestion as to what we do at Buffalo. As the sludge cake is developed, the operator, on a definite schedule depending on the rate of operation, hand picks a small sample, which is placed in an airtight 1-gal. jar. The jars are collected every 24 hr. for sample analysis.

On the question of dried sludge and sludge fertilizer, analysis requires a 0.25-lb. sample per shift. The tare weight of the jars is noted in the laboratory when they are sent out.

James W. McAmis, Superintendent, Water Commission, Greenville, Tenn.:—We have a peculiar problem in that we make a charge for sewer use and we have an industrial plant that furnishes from 30 to 60 per cent of the total B.O.D. load. We have to determine how much they should pay. There is quite a bit of money involved. The question now confronting us is how to divide the B.O.D. load fairly.

This only applies to raw sewage samples, but because of the large solid particles in it, the domestic sewage will have a great deal more large solids in proportion to the B.O.D. content than does the industrial sewage. The composites contain a good deal of solid matter, and it is felt that to break up those solids and take out portions for the analysis after they have been broken up, would be discriminating against the industrial plant. What portions should be analyzed out of the raw sewage?

Dr. Edwards:—At Wards Island we used a homogenizer (Waring blender) to break up the solids for sampling and for analysis. It appears to have no adverse effect as far as the determination itself is concerned, either of suspended solids or of B.O.D., but it does permit the taking of equivalent portions—equivalent in volume, in solids, and presumably in B.O.D.—out of a sample, which may be very heterogeneous to start with.

Mr. McAmis:—If all those solids are broken up won't the B.O.D. value be increased?

V. P. Enloe, Superintendent, Sewage Treatment Plant, Atlanta, Ga.:—At Georgia Institute of Technology, over a period of several months, using a blender, it was found, in comparing raw samples with blended sewage samples, that the blending of the sewage reduced the B.O.D. to a certain extent instead of increasing it.

Sidney L. Allison, Superintendent, Sewer Department, Corpus Christi, Tex.:—I believe the question of solids could be left out. After all, the load on the plant and the basis of it is the B.O.D. A milk plant will contribute a terrific B.O.D. As a matter of fact, it will jump it up to around 800 p.p.m. and it will also drop the pH, which will make it difficult. Therefore, the basis of charge should be the B.O.D. load.

Earl R. Howard, Assistant Engineer, Bureau of Public Works, Hartford (Conn.) Metropolitan District:—Is any appreciable change made in the quantity of sample taken on the quarter-of-daily-flow basis as against the 24-hr. basis?

Dr. Edwards:—Yes. About a quart is obtained on each of these samples, whereas, if taken every hour or every two hours, we would normally get

about four ounces. It is just to get the amount of sample needed for analysis. Of course, the samples by the reduced schedule are already weighted according to flow.

Mr. Howard:—Mr. Studley asked about sampling filter cake. At Hartford, where we use vacuum filters, we have taken about a 6-in. piece of ⅝-in. brass pipe and ground it down to make a circular cutting edge on one end. The pipe is fitted with an internal plunger and with the necessary operating handles to make it operate like an overgrown cooky cutter. Samples taken with this apparatus are kept in a covered glass jar. It works very well.

George W. Martin, Chief Engineer and Superintendent, Green Bay (Wis.) Sewerage District:—We are pretty proud of a couple of automatic samplers we have been operating for five or six years. Each consists of a wooden staff that is driven up and down by two small motors, mounted back to back. Whenever 15,000 gal. of sewage goes through the plant, the flow meter makes a contact and energizes one of the motors, which drives the staff down so that a little cup on the bottom end of the staff is filled. At the low end of the travel the power is switched to the other motor, and the staff is driven up. As the cup reaches the top of its travel it automatically trips, dropping the sample into a jar.

These samplers have been very trouble-free. We think they take a very representative sample, because they take it at a point of turbulent flow. In other words, we take the sample at the point where the sewage leaves the detritus chamber and flows into the clarifier. The effluent of our primary treatment plant is sampled at the point where the sewage again goes over a weir. The samplers do not pick up rags and are easy to clean. Each operator, as he starts on his shift, has to clean up the sampler and keep it going.

Chairman Larson:—Basically, we perhaps are more interested in the matter of automatic sampling *versus* hand sampling. That seems to be the important thing.

At Springfield, we take hourly samples, but sample procurement is only one of the functions of that trip around the plant. At the same time the operator makes a check on his motors and other equipment, so the hourly sampling schedule serves an additional function, and a rather important one.

Fred H. Burley, Superintendent, Sewage Treatment Plant, Detroit, Mich.:—What has been the experience with sample pumps pumping a sample to the laboratory continuously, there either to be taken at stated intervals or connected to an automatic sampler? Also, do sample lines of that kind give trouble with formation of gels or other fungus growths that interfere with proper sampling?

Kerwin L. Mick, Chief Engineer and Superintendent, Minneapolis-St. Paul (Minn.) Sanitary District:—A battery of automatic samplers in our plant is used regularly and very satisfactorily, providing they are carefully maintained. They have been checked many times against hourly or two-hourly grab samples, both on the raw sewage and the settled effluent in the primary tanks; very satisfactory checks have been obtained.

The lines to the samplers are 2-in. or 3-in. pipelines varying in length from about 15 to 50 ft. The pipelines are so valved that we can shut off the flow to the samplers and back-flush them with high-pressure water once a shift to flush out any accumulation or growth that might tend to form. Also, the sampler parts are cleaned with a brush of the test-tube type once a shift. Once a week the sampler parts are washed with a copper sulfate solution to hold down any growths.

The sampling is checked by means of the solids balance. That is, we run the regular solids balance and we compute it on the basis of the laboratory

samples, total solids *versus* suspended solids. Those determinations usually agree within 2 per cent. Then those removals are checked against the actual removals in the plant as measured by the sludge bucket elevator and the filter cake samples and cake scales. They usually agree within 5 per cent. If not, we start looking for trouble.

Some trouble was experienced during the last several months. The quantity of raw sludge solids determined by sampling appeared to be too high when compared with the bucket elevator and the cake scales measurements. By watching the taking of the raw sludge samples, it was found that the 15-min. schedule of sludge sampling during the operation of the sludge pumps was being followed at the start of the pumping period, but neglected at the end of the pumping, when the sludge was thinnest. Of course, that resulted in the raw sludge sample being too strong compared with what was actually pumped, as indicated by the solids balance.

The automatic sampler's principal trouble is that it is timed off a meter electrically. It takes a competent electrician to keep them in proper operation because they do get out of kilter.

Ralph A. Hoot, Superintendent, Northeast Sewage Treatment Plant, Philadelphia, Pa.:—The comments on night sampling are interesting. At Fort Wayne, Ind., we had a man collecting samples of whom we were somewhat dubious. Finally, we hooked up an extra time meter to the laboratory refrigerator door so we could tell when and for how long the door was opened. We didn't know if the man took the sample, but at least we could tell if he opened the refrigerator door and put something in. We soon found out that it took 15 sec. to store a sample of sewage, but only 7 sec. to get one of the candy bars kept there.

We had quite a little fun before the operators knew what was going on, and we could tell on which shifts samples were not stored. Incidentally, although the union came back with the charge that this was unfair to organized labor, one operator actually was discharged for failure to open that refrigerator door the proper number of times on his shift.

At the Philadelphia Northeast plant we are rehabilitating an old building into administration and laboratory facilities. The laboratories will be on the second floor, where there are windows so placed that they look right down on the battery of tanks. The operating chemist on duty is going to be where he can watch the men going about on the sampling routine.

Chairman Larson:—Who is going to keep the operating chemist awake?

The human element in this matter of sampling seems to be the all-important one. It all boils down to just how seriously you can impress on your operators the necessity of proper samples. Automatic samplers remove that human element, but I do think they have some other drawbacks.

Lubrication of Equipment

John W. Johnson, General Manager, Buffalo (N. Y.) Sewer Authority:—For many years, lubrication had received only scant attention, probably due to the fact that although solutions were possible to most engineering problems, there were very few convenient formulas that would provide ready answers in the practice of proper lubrication. Most of the information accumulated on the subject has been acquired by practical experience with trial and error methods.

Late in the last century the true nature of the oil film theory was discovered; we are fortunate that progress has been in the right direction. Suppliers and users of oil are beginning to realize that lubrication can no longer be left to guess work and that price should not be a factor in selection of materials.

Research by major companies has at last removed much of the conjecture formerly applied to the subject. Most oil firms now have staffs of qualified lubricating engineers able to inspect a plant and to report intelligently on the lubrication conditions of all engines and machinery; to point out and estimate the value of proper improvement in regard to savings in power and lubricants. These men are thoroughly trained in the characteristics of their various products so they can recommend the correct grades for any kind of machinery.

In producing lubricating oils, refiners are less dependent than heretofore on the nature of the crudes. New and improved refining methods have eliminated undesirable ingredients. Larger varieties of crudes are now with greater ease being made into oils with noncarbonizing and nonemulsifying properties. Such new products as extreme pressure lubricants and those with added anticorrosion inhibitors are now obtainable. Lubricants with viscosities resistant to oxidating heat and cold are being formulated with an inert media mixed with very oily constituents to give desired body and oiliness.

Despite these developments by the industry, proper lubrication is still dependent upon the care and techniques offered by operating personnel. Storage of lubricants is an important consideration, as dirt and grit in oil or grease will have damaging effect on equipment. Certain metal containers have adverse effects on lubricants; for instance, zinc is active when in contact with fatty oils, so galvanized containers should not be used for this type. Copper or brass are undesirable in some oiling systems because of adverse chemical reaction.

The methods of applying lubricants should be considered. Hand oiling is most inefficient, as there is usually a feast or a famine in the supply. Bottle oilers are not too reliable, because the variable length of the lubricating spindle feeds too much or too little. Wick-type lubricators are reasonably satisfactory if the level in the oil cup falls slowly. The drop feed cup allows a controlled flow through a needle valve, but the rate is dependent on the temperature and viscosity of the oil. In the case of waste-packed bearings, cotton waste is not suitable because of the surface glaze developed and the lack of elasticity. Wool waste or a combination of wool and cotton is satisfactory. Other types include ring, chain, and roller oiling from a reservoir by circulation, in which case it is safest to use light oil. In some instances moving parts are submerged in a bath of oil; in others, the splash system is used. There are also gravity and pressure circulating systems; mechanical force feeds by pumps; and hydrostatic lubricators, in which the lubricant is atomized. Where designers have failed to provide the proper type of application, operators must remedy the condition.

It is well to point out that so-called "oilless" bearings are not actually oilless. Also, they are not able to operate indefinitely without replenishment of the lubricant. These bearings are made from porus material impregnated with 10 to 20 per cent oil by volume or from graphite-impregnated bearing metal.

Experience indicates that the more common type of bearing used in sewage plants, and consequently accounting for most failures from faulty lubricants, is the ball or roller bearing. Therefore, the balance of this paper is confined mostly to this subject.

There are several functions of the lubricant in respect to operation of antifriction bearings. The most important of these are that the lubricant must:

1. Have a viscosity high enough to permit formation of a load-supporting

film between the balls or rollers and their containers and races.

2. Be capable of wetting the entire surface and also of acting as a preventative against corrosion.

3. Provide a seal to prevent entrance of any solid matter into the housing.

4. Aid in dissipating additional heat.

This type of bearing has lower friction than the plain bearing and most of the trouble which develops is from too much lubrication at too frequent intervals. If too much oil is used there is generated an unnecessary fluid frictional heat, which causes an increase in the bearing temperature with a resultant power loss and a possible leakage of the lubricant. If too much grease is used and the housing is full, the churning of grease will raise the bearing temperature and break down the grease structure, with consequent blowing out of grease seals. If the housing is tight and lubrication is correct, antifriction bearings do not require attention oftener than once in three months.

Oil is preferable to grease for antifriction bearings, because it offers less resistance to motion and does not contain thickening agents. It is, however, difficult to keep oil bearings tight. If oil is used, care must be exercised in using the proper viscosity for varying operating temperatures. Speed of equipment also must be considered. Slow speed requires heavy oil; high speed, light oil. Bearings in warm locations require heavy oil; in cold locations, light oil. In extremely high-speed operation, it is best to apply small quantities of oil, preferably by the atomized or mist method.

The main drawback of using grease for lubrication of antifriction bearings is due to the materials combined to form the greases. Most greases are a combination of oil and soap. If separation should occur, the soap is caused to cake on the inside of the bearing. Sodium soap grease has a clingy fibrous structure with little tendency to separate on heating. It will regain its original structure on cooling; however, it will emulsify. Calcium soap greases, on the other hand, are buttery and are only suitable for use at temperatures below 160° F. They are good for only low or moderate speeds, but will not emulsify. Because of these variable properties, greases manufactured from both sodium and calcium soaps have provided lubricants with high melting points, are nonemulsifying, and are suitable for a wide range of conditions.

Several pertinent suggestions for lubrication of antifriction bearings are:

1. Fill the reservoir only to a depth of one-third; oil only to a sufficient depth to submerge the lowest balls or rollers.

2. Add new lubricant infrequently, and then only in limited quantities.

3. Dismantle and clean all parts once every year. However, if a bearing is subject to high temperature more frequent cleaning is required.

The need for conservation of oils and greases cannot be overemphasized, as these materials are costly and are derived from our natural resources. Wastes and misuse of these valuable aids should be most emphatically eliminated. For instance, from economy and safety viewpoints, excess oil in an air compressor is wasteful of oil and harmful to equipment. Excess oil will enter the coolers and receivers and clog the valves. With this film adhering to the surface, fires or explosions may result from the increasing heat of the compressing air. Practice of conservation on a national scale is most important, particularly in view of the enormous quantities of oil used up in a war. Numerous gushers have come in producing gigantic quantities of crude oil, some flowing over 100,000 bbl. per day, but within a few years have gone dry and now produce only brackish water.

In conclusion, some factors which

will insure good lubrication of mechanical equipment, if followed, are as follows:

1. Provide lubricants designed for the service and purchased from reliable firms. The lubricants should be selected on the basis of the equipment manufacturers' recommendations or as the result of a lubrication survey by a reliable oil firm.
2. Provide proper lubricant storage and handling facilities, giving particular emphasis to containers, danger from spills of oils or greases, fire prevention, and general good housekeeping.
3. Provide proper lubricating devices, either by the manufacturers and designers or through revisions by the operating department as necessary.
4. Provide instructions to operating personnel as to various uses of lubricants, various types of lubricants, and methods of application.

Uhl T. Mann, Superintendent, Ley Creek Sewage Treatment Plant, Syracuse, N. Y.:—Isn't it rather important to provide some method of filtering oil in gas engine crankcases to remove moisture? Also, there would appear to be a very large number of lubricants for plug valves.

Lovell J. Lukrofka, Sanitary Engineer, Springfield, Mo.:—We have two gas engines, and use an oil reclaimer. The process is working very satisfactorily and is simple enough for the operators to be able to do the reclaiming job while carrying out their regular duties on the shift. During each shift, 8 gal. of the oil are reclaimed and the machine is made ready for continued use on the next shift.

The oil reclaimer has been in operation now some seven years; there has been little or no mechanical trouble with it. Cost analysis has proven that you can reclaim the oil and have less carbon trouble with gas engines than by any other means known to us.

Frank I. Vilen, Superintendent, Sewage Treatment Plant, Kenosha, Wis.:—Is one type of oil used throughout the plant and reclaimed, or are various types of oils and inhibitors used? Also, what do you have left when you get through reclaiming?

Mr. Lukrofka:—The only oil reclaimed is that used in the gas engines. By a continuous cycle, the oil is pumped from the oil reservoir to the reclaimer, then returned to the engine crankcase.

W. B. Walraven, Engineer, Springfield (Ill.) Sanitary District:—Reclaiming of oils does save a good deal of oil. Our engines at Springfield have a comparable type of filter on them that is operated continuously. The oil obviously becomes heavier. At the end of a month of operation, if the filters are kept clean, we have a more expensive and better oil than that with which we started. In order to cut it down, one must put in a lighter grade of oil and a sweetening oil.

Incidentally, one of the major oil companies—Texaco—puts out a wonderful set of bulletins on the general subject of lubrication in plants, which anyone may get by asking for it. I presume other oil companies supply the same type of information. Obviously, these bulletins cover fields far wider than our own, so that a large part of the material is not applicable to sewage treatment plants. Nevertheless, sooner or later the answers to practically all of our lubrication questions can be found.

Mr. Johnson:—Lubrication of a plug valve is quite an important consideration. We went for two years without knowing that they had to be lubricated. Therefore, when we went to close the valves, it was difficult. A company representative was called who aided in opening the valves without damaging them. When he provided us with cylinders or sticks of grease to insert into the end of the valve, it came as a surprise to all. Our operating instructions didn't cover that. However, the plug valves have been checked ever

since. My experience has been only with the cylindrical type, but it really does the job. The valves were in use in gas lines.

James H. Blodgett, Superintendent, Sewage Treatment Plant, Columbus, Ohio:—We had a similar situation. We didn't know that plug valves had to be lubricated until we finally had to close one. The use of stick lubricant in our plug valves has been eliminated by putting on ordinary button-type fittings so a high-pressure grease gun can be used.

Glenn Searls, Superintendent, Sewage Treatment Plant, Rochester, N. Y.:—The company that manufactures the type of plug valves used in the Rochester plant makes a study of individual conditions and makes recommendations as to the lubricant. I have had a little experience with that. A lubricant recommended when the valves were bought didn't work out satisfactorily, but among their many types of lubricants they found one that did. Since making the change we have had no trouble. Possibly, consulting the company that makes the valves might be of some help.

Stanley T. Barker, State Department of Health, Albany, N. Y.:—One great difficulty with grease fittings is to know when to stop applying grease. I wonder if the modern roller bearing or the modern ball bearing has any method to tell you when to quit. I know that my mechanics pushed grease in until it started coming out in every direction, which is obviously too much. But how do you know when to stop?

Mr. Johnson:—Of course, that is difficult, particularly if the housing is closed. For some years we had the trouble resulting from bearings being too full. A company developed a grease fitting with a spring arrangement that opened a relief slot when a predetermined pressure was reached within the housing. Thus, upon the appearance of clean grease from this slot, the application was immediately stopped.

Fred H. Burley, Superintendent, Sewage Treatment Plant, Detroit, Mich.:—A routine schedule on which one of our operators covers all of the plug valves in the plant is very advantageous. A record is kept of that greasing schedule. The grease used is the manufacturer's recommended grease. The schedule involves not only lubricating the plug valve, but also opening and closing it to keep it well exercised. That is quite important.

W. W. Mathews, Superintendent, Gary (Ind.) Sanitary District:—Mr. Johnson's experience is somewhat similar to ours, although we have found that if you follow the manufacturer's recommendations as to various greases, maintenance troubles will be reduced. If a valve is used a great deal as a routine operation (such as sludge-pumping valves and inlet and outlet valves) that valve can be used a long time before you have any trouble. But there are always some valves like the sludge-control valves that may not be used oftener than once a month.

Chairman Larson:—The by-pass, for instance—you don't use that very often!

Mr. Mathews:—I am referring to sludge lines. Unused valves certainly will stick, even when the manufacturer's directions as to grease are followed. I will be frank to admit that the only time we service any of those valves is when an operator reports that one cannot be opened. Then the maintenance man takes it apart, cleans it and puts in fresh grease. Grease will set hard and I have known the operators to put a pipe extension on the wrench and still be unable to operate the valve. Then cleaning and fresh greasing is required.

Chairman Larson:—Am I to understand that this is a condemnation, or at least a criticism, of plug valves as a whole?

John J. Wirts, Assistant to Commissioner, Dept. of Public Utilities, Cleveland, Ohio:—I can answer that question. I think we have all operated a hard cider barrel or a wine barrel with an ordinary wooden plug. Not too much trouble is experienced if it is operated enough. We seem, however, to have been subjected to a lot of advertising on the value of certain lubricants for certain valves. If a pressure-gun fitting is put on a valve so that some grease is forced through, it may work. But even that is not the whole answer, I am sure.

Paul L. Smith, Operator, Sewage Treatment Plant, Baltimore, Md.:—I had some experience with plug valves on chemical lines. The lubricant shipped with the particular valves looked almost like a tar. We just couldn't operate those valves at all; in trying to force the lubricant in we split the bottom out of the valve. A change was made to a different type of lubricant that looked almost like a candle, and we still continued to have trouble. Later, use of silicon grease proved very much better. But the valves, because of the acid, became etched and rough and still weren't right. So we changed to different valves.

The other point I want to bring up concerns the displacement mechanism of the gas meters. Because of the moisture in the gas, we had emulsion in our bearings, which were self-lining double ball bearings. Those bearings had to be replaced about every three months. I had some flushing oil on hand, which is really a No. 10 oil with quite a bit of detergent in it. So I thought I would try that. After using the flushing oil, more than three years elapsed without our having to touch the bearing at all, as compared with probably three months prior to that.

Occasionally the gas meters would stick because of a piece of scale or some other foreign substance. The clearance, of course, is very small. Installation of copper tubing running to a reservoir having a visible needle valve and sight line allows dropwise addition of kerosene to the veins of the meter. The kerosene has eliminated practically all the sticking trouble.

V. P. Enloe, Superintendent, Clayton Sewage Treatment Plant, Atlanta, Ga.:—How was the flushing oil used?

Mr. Smith:—The meter bearings have a housing with an oil well that is kept full. The oil recommended by the manufacturer emulsified and the bearings froze. Substitution of the flushing oil eliminated that trouble and seemed to keep the bearings in much better shape.

Mr. Enloe:—Our trouble seems to stem from too much moisture in the gas. For some reason, the moisture runs out along the shaft, through the bearings, and down into the oil well; it soon displaces the oil. The oil wells have to be drained about every two weeks and new oil put in. I thought perhaps you had some way of flooding the oil well and forcing the water back to keep its accumulation from diluting the oil.

Mr. Smith:—We don't have that much water. Ahead of our gas meter there is a large drip pot, which captures some of it. But there is enough carried over so that we get some condensate in the meter.

Chairman Larson:—This matter of silicon greases is new. I don't believe Mr. Johnson mentioned the matter in his discourse.

Mr. Johnson:—Perhaps one forgets the thing that is most evident. We have been using silicon grease for about two years. Without exception we use it for everything—high-temperature or low-temperature locations, even in place of oil on cast-iron bearing surfaces.

Mr. Enloe:—We seem to be neglecting the bearings that we started talking about; also, the breaking of grease seals by forcing grease into them. Someone asked a question about how that could be avoided. I believe the answer was having a certain type of pressure relief

valve so that too much pressure couldn't be put on the bearing. The housings of such bearings do have relief plugs on the far side from the points where they are greased. It is good practice to take that plug out before starting to put in the lubricant. We do that, but an industrial oil engineer has advised us that if those bearings are properly greased the lubrication will last about six months despite the amount of use.

Anyone who has this problem should get in touch with an industrial oil engineer and have him go over the plant and advise on how to take care of the bearings. We were just breaking grease seals all over the plant by forcing grease into the bearings, despite the fact that the relief plugs had been taken out of the far side. This was because the grease would get hard and the plugs would stop up.

J. M. MacCrea, Manufacturers' Agent, Syracuse, N. Y.:—The motor manufacturers have covered part of what I have to say. They have pointed the way to the proper roller and ball bearing grease lubrication by means of these plugs, one on one side of the bearing housing and one on the other. In most cases these are actually plugged with ⅛-in. plugs. The operator should take both plugs out and put an Alemite fitting in one, thereby allowing him not only to flush the grease out, but also to properly lubricate the bearing without too much pressure.

I would like to see the pump companies, for instance, put such a relief on the other side of the bearing housing to allow for flushing out old grease, because, as has been pointed out, six months is generally ample for regreasing.

Thomas C. Thompson, Maintenance Engineer, U. S. P. H. S., Washington, D. C.:—It is one thing to take a plug out of the bottom of a pump in normal operation; it is another thing to take it out when you are working on a system of flash drying, where the dried sludge permeating the air is fine enough to go through paper. To take a plug out under those conditions would seriously reduce the life of the bearing.

TIPS AND QUIPS

Odor Control in Effluent Used for Lawn Spray

Effluent water is used for lawn sprinkling at the Winnipeg, Canada, sewage treatment plant. However, complaints of odors from the sprayed water presented a problem. Investigation revealed that about 15 p.p.m. of chlorine was required to remove objectionable odors. Consequently, means were sought by Superintendent D. L. McLean and Chemist O. Petursson for chlorinating that portion of the effluent so used.

An economical solution to the problem was found in a portable chlorinator borrowed from the city Water Department. During the period from June to September, 1949, this 50-lb.-per-day machine used a total of 192 lb. of chlorine for 141 hours of spray from 18 sprinklers at a time. Complaints of odors from this source were entirely eliminated.

Plant History

The Plainfield (N. J.) Joint Meeting has recently taken a big step in acquainting its taxpayers with the developments, past and future, of the sewer system and treatment plant serving its area. In an attractive 36-page booklet containing many interesting pictures of the plant and the personnel

involved, the reader is given the background and history of the sewage problem in the area, the 1913 agreement under which the Joint Meeting was formed and now operates, a description of the original (1916) facilities and subsequent plant growth, and a general description of the plant processes and operation. Current budget information and proposed improvements complete the presentation.

The Joint Meeting officers, and Superintendent Andrew Palmer in particular, are to be congratulated for this fine piece of public relations work in the pioneering cooperative effort of the three municipalities involved.

Water Stretching Program

When the Quaker Oats Company faced the problem of providing large additional water sources at its Pekin, Ill., paperboard mill, the solution was found in improved water treatment and re-use and by cleaning the mill's wells to increase their capacity.

Although waste process water had already been reduced from 10,000 gal. to 7,000 gal. per ton of product, consultants pointed out that even the latter figure could be cut to 3,500 gal. per ton by using treated white water on the felt showers instead of fresh water. This is to be accomplished by a save-all, not only to condition water for such re-use, but also to furnish a degree of effluent treatment satisfactory to state regulatory authorities.

The unusable underflow from the sedimentation-type save-all is to be used to sluice ashes to a disposal area, thus solving the save-all sludge problem and saving an additional 18,000 g.p.d. of fresh water it had been proposed to use for sluicing the ashes.

Treatment of the well water with chlorine and a toxic additive fed at the pump head will do away with biological fouling of the turbine condenser by slime forming bacteria, thus eliminating the necessity for daily blowing of the condenser with scarce fresh water.

Drum and Barrel Covers

The latest in gadgets for keeping things tidy are neoprene-impregnated paper covers to fit standard 55-gal. drums. Made by the Chase Bag Co., Chicago, Ill., the single-ply covers are 2 ft. in diameter and have a 4-in. skirt hemmed with an elastic band around the bottom. When slipped over the drum, the elastic holds the cover in place, keeping the contents dry and clean.

Might be worth thinking about for fly, odor, and moisture control on skimmings, grit, and grease containers and on other storage drums.

Smog Elimination

Meteorological observations in connection with air pollution abatement operations at the Hanford, Wash., works of the Atomic Energy Commission may provide the answers to "smog" conditions. Indications are, according to M. L. Barad, meteorologist for the General Electric Company, operators of the plant, that temperature conditions within the first 300 or 400 ft. of air cause fogs, keep stack gases from dispersing, and result in smog conditions.

The suggested remedy is to make all factory stacks emitting waste gases at least 300 ft. in height, and preferably taller, thus discharging the gases at a level where air temperature conditions will cause them to rise rather than settle.

Operators *vs.* Machines

The dramatic development of "electronic brains" during the past few years is such as to excite the imagina-

tion of even the most unmathematical of minds. From the first crude "mechanical brain," a sprawling 30-ton giant that occupied a large-sized room, engineers and scientists by selective "breeding" have been able to refine the strain and produce the compact and streamlined mathematical miracle workers of today. Present models, in addition to being able to solve almost any conceivable problem from the simplest business arithmetic to the most complex in the realms of higher science, also have "memories" and sort and record the information processed through their "brains."

What next? When reading about these all-but-human machines, one's thoughts are apt to wander slightly into the mental area—reserved for man and jealously guarded from machines—known as day-dreaming. Is it possible that engineers may someday build treatment plants run entirely by mechanical and electronic "slaves"? Of course it is. Even now the average operator has at his command literally hundreds of "slaves" in the form of automatic controls, safety devices, etc.

Despite all the fancy equipment and controls born of designers' ingenuity, however, there is no indication that they have been or will be able to supplant with robot minds that experience and judgment brought to bear on the problems of operation by competent, trained operators. No machine yet foreseeable will be able to determine when to draw sludge, increase the chlorine dosage, paint the primary tank railings, or clean the No. 4 sludge bed, much less to detect the multitude of maintenance and repair jobs.

Must Be Real Emergency

The Washington State Pollution Control Commission, noting in its "Progress Report No. 26" that ". . . it has become too much of a general practice to by-pass sewage treatment plants for numerous reasons which cannot always be classified as emergencies," has adopted the following regulation to control the practice:

"Emergency Notification. Whenever it becomes necessary to by-pass a sewage treatment plant or any major unit thereof, the owner shall immediately notify the State Department of Health or the State Pollution Control Commission by telephone or telegram."

Most state regulatory bodies presently require such notification. However, whether required or not, it is always good practice to keep the proper state authorities informed of any unusual conditions necessitating by-passing of your plant.

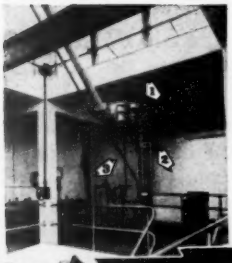
Then too—think of your conscience!

For Meritorious Service

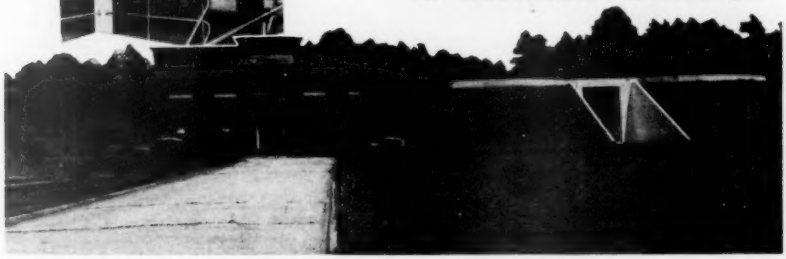
An award for meritorious service in the field of sewage works operation was presented to Carl B. Carpenter, superintendent, Hammond (Ind.) Sanitary District, at the Annual Meeting, Indiana Sewage Works Association, December 8, 1950. In selecting Mr. Carpenter the committee said:

"The recipient of the award has for many years combined his talents as an engineer and administrator to make an enviable record in the field of sewage works operation. Mr. Carpenter has not only maintained an outstanding reputation for his success in sewage works operation but has also been a leader in the affairs of the Indiana Sewage Works Association and the Federation of Sewage Works Associations. Mr. Carpenter has been president of both the Indiana Sewage Works Association and the Central States Sewage Works Association."

We congratulate Mr. Carpenter on a job so well done as to warrant this signal recognition by his colleagues!



THE LAST WORD IN SEWAGE TREATMENT AT CHARLOTTE, N.C.*



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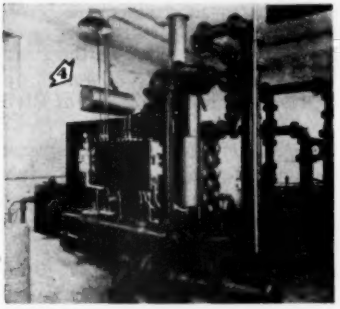
At Charlotte, N. C., both the Irwin Creek plant and Sugar Creek plant, built in 1903, consisting of sedimentation and contact filters, were modernized in 1928, by conversion to activated sludge plants. In 1950 the Irwin Creek plant underwent a second stage of modernization and enlargement embodying P.F.T. Floating Covers, (1) Gas Safety Equipment, (2) Cover Position Indicators, Supernatant Selectors, and (3) Sight Glass Control Gauges and (4) Digester Heaters and Heat Exchangers. Activated sludge portion of this plant was extended and redesigned to incorporate the P.F.T. Kraus Process. Plans are underway to similarly enlarge the Sugar Creek plant. These projects are under direction of J. N. Pease & Co., Consulting Engineers, Charlotte, N. C.



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Proceedings of Member Associations

NORTH CAROLINA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 22nd Annual Meeting of the North Carolina Sewage and Industrial Wastes Association was held at the Washington Duke Hotel, Durham, N. C., November 13–15, 1950. The meeting was held jointly with the 30th Annual Conference of the North Carolina Section, AWWA. Total registration for both associations was 222, of which 46 were Sewage Works Association members, representing 51 per cent of the total membership of the Association.

The meeting opened on November 13 with a welcoming address by city officials.

About one-half of the technical papers were devoted to waterworks topics, the others being on topics of interest to the sewage works men. These topics were:

"The Present Crisis in Municipal Finance," by George Franklin, general council, North Carolina League of Municipalities.

"Need of Civil Defense in the Present Emergency," by E. Z. Jones, director, North Carolina Council of Civil Defense.

"Current Developments in Stream Sanitation Programs," by J. M. Jarrett, director, Sanitary Engineering Division, North Carolina State Board of Health.

"Public Relations," by M. T. Dunlap, personnel director, Carolina Power and Light Company.

Tuesday afternoon was devoted to a sewage works discussion panel, which aroused considerable discussion from the floor and was considered quite informative. Professor Emil T. Chanlett, School of Public Health, University of North Carolina, served as leader and was assisted by R. S. Phillips, S. E. Harris, Wade G. Brown, and F. R. Blaisdell. Subjects such as "Regulating use of Sanitary Sewers," "Sewer Service Connection Policies," "Laboratory Control of Sewage Treatment," and "Need for Qualified Plant Operators" were discussed during the session, which lasted all afternoon.

The concluding session on Wednesday morning was made up of papers on sewage and industrial waste subjects, as follows:

"Rendering Plant Waste Studies," by Professor Marvin Granstrom, School of Public Health, University of North Carolina.

"Selection of Sewage Treatment Process," by Ralph E. Fuhrman, president, FSIWA.

"Industrial Waste Studies," by John C. Grey, senior sanitary engineer, North Carolina State Board of Health.

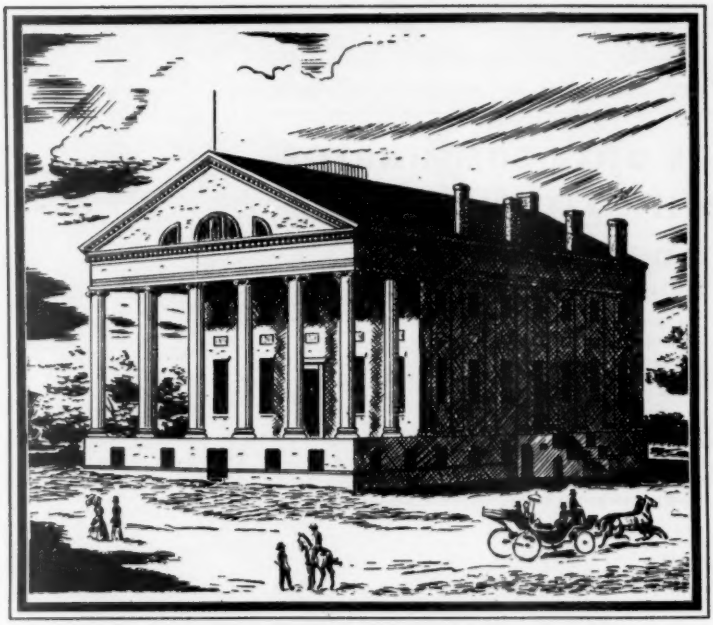
The Annual Business Meeting was held on November 14. The most important item of business was the action taken by the Association in changing its name to the North Carolina Sewage and Industrial Wastes Association.

At the banquet on November 14, an excellent address was delivered by Dr. Paul Gross, vice-president of Duke University, on the subject "The Development of Atomic Energy and its Use for Civilian Needs."

Officers elected for 1950–51 were:

Chairman: W. W. Adkins, Asheboro.
Vice-Chairman: H. F. Davis, Charlotte.
Secretary-Treasurer: E. C. Hubbard, Raleigh.

E. C. Hubbard,
Secretary-Treasurer



Richmond's State Capitol, completed in 1792, as it looked 100 years ago

Richmond, Virginia, has a cast iron water main in service that was installed well over a century ago. In those stage-coach days, *traffic shock* caused by heavy trucks and buses was, of course, undreamed of. There were no sewers and other underground conduits to cause soil disturbances and settlement. Yet this rugged old pipe had what it takes in shock-strength and beam-strength to meet unforeseen stresses. Strength, as well as effective resistance to corrosion, are prerequisites of long life in pipe to be laid under city streets. This is evidenced by the fact that cast iron water and gas mains, laid over a century ago, are still serving in the streets of more than 30 cities in the United States and Canada. United States Pipe and Foundry Company, General Offices, Burlington, New Jersey. Plants and Sales Offices Throughout the U. S. A.

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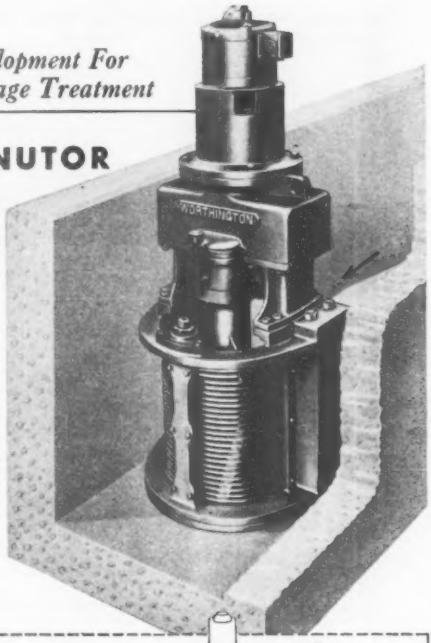

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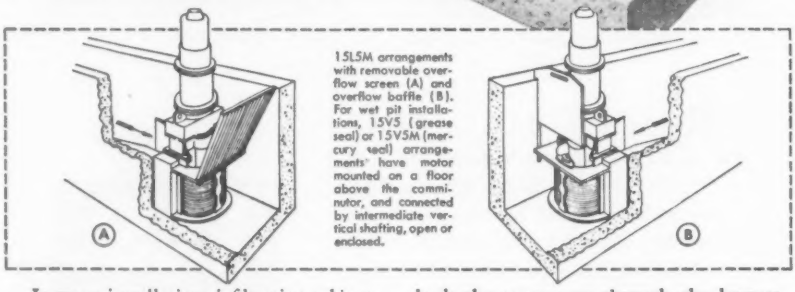

15L5M arrangements with removable overflow screen (A) and overflow baffle (B). For wet pit installations, 15V5 (grease seal) or 15V5M (mercury seal) arrangements have motor mounted on a floor above the comminutor, and connected by intermediate vertical shafting, open or enclosed.

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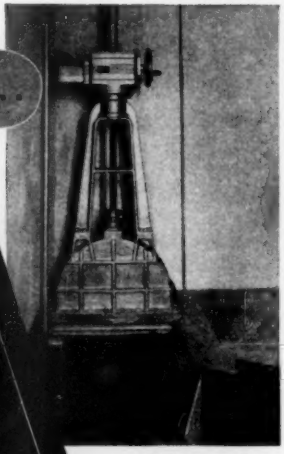

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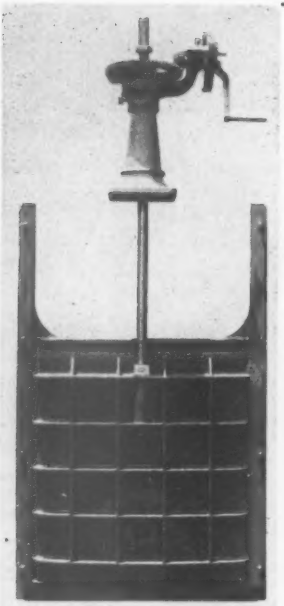

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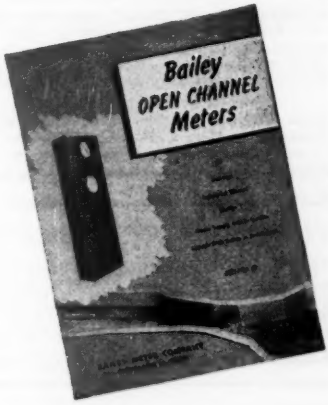

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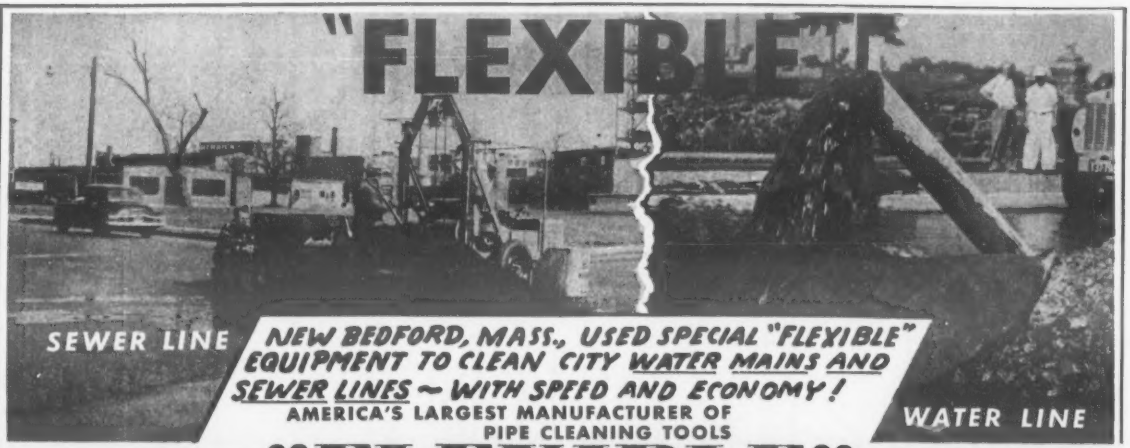
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INDEX TO ADVERTISERS

	Page
American Brass Company	151a
Bailey Meter Company	151a
Builders-Providence, Inc.	152a
Cast Iron Pipe Research Association	142a
Chicago Pump Company	123a
Dorr Company, The	144a
Everson Manufacturing Corporation	150a
Fairbanks, Morse & Co.	134a
Flexible Sewer-Rod Equipment Company	150a
General Chemical Division (Allied Chemical & Dye Corp.)	126a
General Electric Company	129a
Inertol Company, Inc.	152a
Infilco, Inc.	131a
Iowa Valve Company	149a
Jeffrey Manufacturing Company	140a
Morse Bros. Machinery Company (Fairul Gate Division)	141a
Nordstrom Valve Division (Rockwell Manufacturing Company)	138a
Pacific Flush Tank Company	148a
Portland Cement Association	139a
Rockwell Manufacturing Company	138a
Simplex Valve and Meter Company	127a
Snow Irrigation Supply Company	150a
U. S. Pipe and Foundry Company	147a
Vapor Recovery Systems Company	152a
Wallace & Tiernan Company, Inc.	Back Cover
Wood Company, R. D.	152a
Worthington Pump and Machinery Corporation	148a
Yeomans Brothers Company	126a

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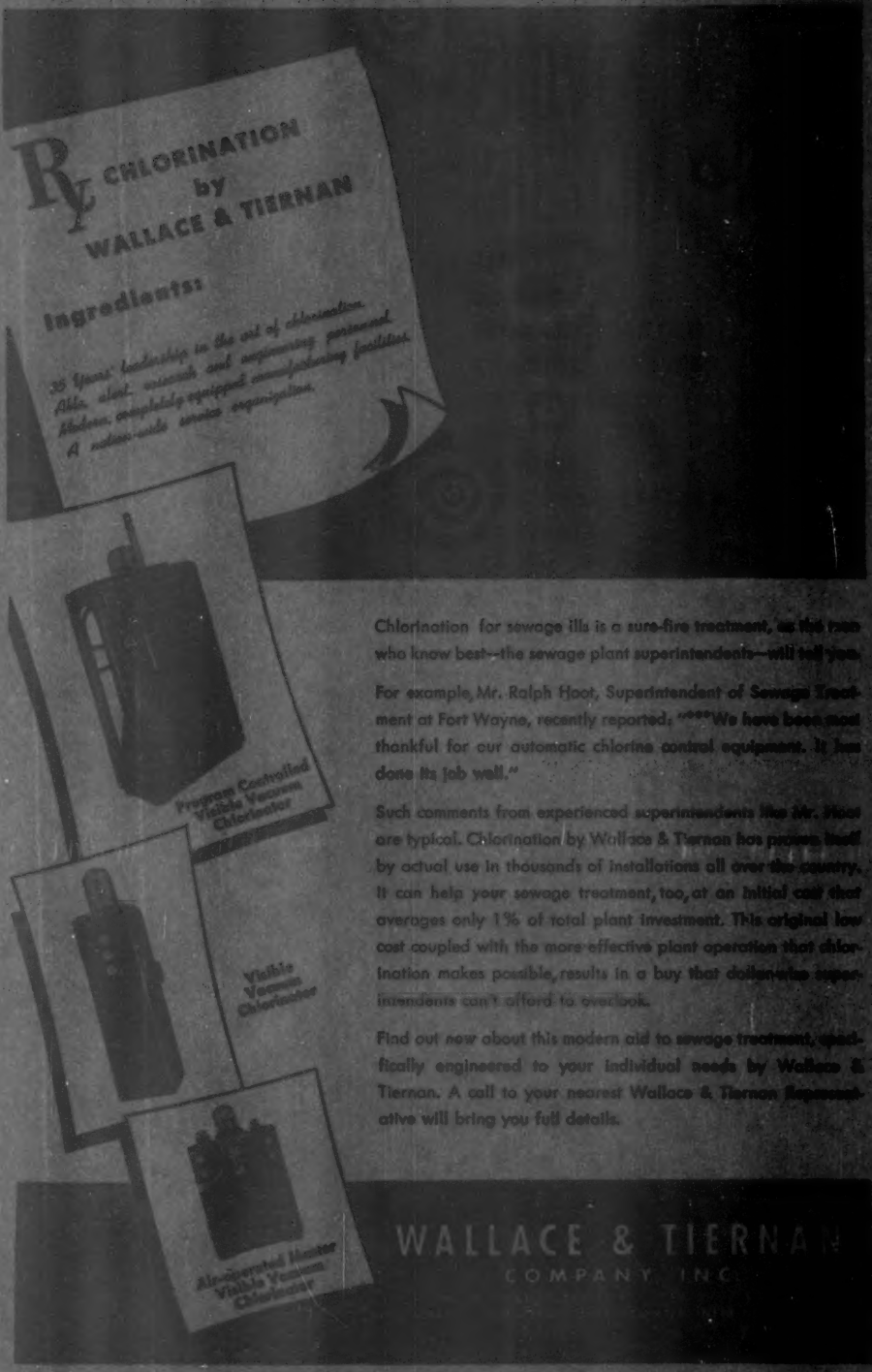

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